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PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XLIV—No. 1

AMERICAN
SOCIETY OF
CIVIL
ENGINEERS
FOUNDED
1852

January, 1918

Published at the Headquarters of the Society, 33 West Thirty-ninth Street, New York, the Fourth Wednesday of each Month, except June and July.

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Entered as Second-Class Matter at the New York City Post Office, December 15th, 1896.
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PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852)

VOL. XLIV—No. 1

JANUARY, 1918

Edited by the Secretary, under the direction of the Committee on Publications.

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NEW YORK 1918

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American Society of Civil Engineers

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TO CODIFY PRESENT PRACTICE ON THE BEARING VALUE OF SOILS FOR FOUNDATIONS, ETC.: Robert A. Cummings, Edwin Duryea, E. G. Haines, Allen Hazen, James C. Meem, Walter J. Douglas.

ON THE REGULATION OF WATER RIGHTS: F. H. Newell, W. C. Hoad, John H. Lewis.

TO REPORT ON STRESSES IN RAILROAD TRACK: A. N. Talbot, A. S. Baldwin, G. H. Bremner, John Brunner, W. J. Burton, Charles S. Churchill, W. C. Cushing, Robert W. Hunt, George W. Kittredge, Paul M. LaBach, C. G. E. Larsson, G. J. Ray, Albert F. Reichmann, H. R. Safford, F. E. Turneaure, J. E. Willoughby.

◆

The Reading Room of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

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Vol. XLIV. JANUARY, 1918. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

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SOCIETY AFFAIRS

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MINUTES OF MEETINGS
OF THE SOCIETY

December 19th, 1917.—The meeting was called to order at 8.30 P. M.; Director Alfred D. Flinn in the chair; Chas. Warren Hunt, Secretary; and present, also, 144 members and 22 guests.

A paper by George Perrine, M. Am. Soc. C. E., entitled "Construction Problems of the Manhattan-Bronx, and Lexington Avenue Subway Junction and Queensborough Tunnel Connections", was presented by the author and illustrated with lantern slides.

The paper was discussed by Messrs. John H. Myers, C. E. Carpenter, Robert Ridgway, C. V. V. Powers, Paul G. Brown, Robert A. Shailer, and H. H. Quimby.

The Secretary announced the following death:

Henry Augustus Herrick, of Butte, Mont., elected Member, May 7th, 1890; died December 14th, 1917.

Adjourned.

January 2d, 1918.—The meeting was called to order at 8.30 P. M.; Director Alfred D. Flinn in the chair; Chas. Warren Hunt, Secretary; and present, also, 64 members and 7 guests.

The minutes of the meetings of November 21st and December 5th, 1917, were approved as printed in *Proceedings* for December, 1917.

A paper by Benjamin F. Groat, M. Am. Soc. C. E., entitled "Ice Diversion, Hydraulic Models, and Hydraulic Similarity", was presented by the author and illustrated with lantern slides.

The paper was discussed by Messrs. C. E. Fowler, J. Waldo Smith, T. Kennard Thomson, and the author.

The Secretary announced that the Ordnance Department of the Army had established boards of officers in all the large manufacturing centers of the country for the purpose of recruiting and commissioning officers qualifying for ordnance service, and that the Board for New York and vicinity is now in session at the Headquarters of the American Society of Mechanical Engineers, 29 West 39th Street, New York City, where applicants would be furnished with the necessary forms and instructions.

The Secretary announced the following death:

Joseph Hobson, of Hamilton, Ont., Canada, elected Member, February 5th, 1890; died, December 19th, 1917.

Adjourned.

SOCIETY ITEMS OF INTEREST

Report of Representatives of the American Society of Civil Engineers on the Naval Consulting Board

To the Board of Direction
American Society of Civil Engineers:

The representatives of the American Society of Civil Engineers on the Naval Consulting Board, appointed as members of that Board by the Secretary of the Navy, on nomination from the Board of Direction of the Society in July, 1915, feel that a brief report should be made at this time regarding the activities of the Naval Consulting Board, and that this report should be set forth in the records of the Society as indicating one phase of the participation of the Society in the present war program and activities.

The Naval Consulting Board is made up of two representatives of each of the following Societies:

American Aeronautical Society,
American Society of Automobile Engineers,
The Inventors' Guild,
American Chemical Society,
American Institute of Electrical Engineers,
American Society of Civil Engineers,
American Society of Mechanical Engineers,
American Institute of Mining Engineers,
American Electrochemical Society,
American Society of Aeronautic Engineers,
American Mathematical Society.

In addition to the above, Mr. Thos. A. Edison was appointed at large as a member of the Board by the Secretary of the Navy.

It is worthy of note that, in addition to the two direct representatives of the Society on the Board, four other members of the same are also members of the American Society of Civil Engineers.

The purpose and functions of the Board are indicated by the following quotation from its By-Laws, which were prepared under the direction of the Secretary of the Navy, and which have been approved by him.

"*Purpose.*—The purpose of this Board shall be to assist the United States Navy Department in any manner that it may, by supplying technical advice when called upon by any Bureau or Board of the Department, organized by law, or appointed by the Secretary of the Navy and to bring to the attention of the Navy Department through the proper channels such technical matters as it considers to be of value to the Government with suggestions and recommendations relating thereto.

"*Functions.*—The Board, in addition to the consideration of such matters as may be referred to it by the Navy Department, or any of its

Bureaus or Boards, may of its own initiative, or through the initiative of any of its Committees, take up any matters which it or such committees may deem advisable and in the interest of the Naval service formulate reports thereon and submit same through the proper channels to the Navy Department for its consideration."

The active work of the Board is carried out through twenty-one committees each dealing with problems in its own special field.

From the time of its formation until the severance of diplomatic relations with Germany, regular monthly meetings were held in New York City, at which committee reports were received and acted on. Since the latter date, regular meetings have been held in Washington every two weeks.

In addition to study of and reports on thousands of inventions and ideas, the Board has dealt with a number of broader problems of which the following are examples:

Recommendation for the establishment of a Naval Experimental Station and Laboratory. Arguments before the Naval Affairs Committee of the House of Representatives leading to the appropriation of funds for this purpose.

Initiation of and carrying out of an industrial census of the United States during the winter of 1915-1916, which was transferred to the Council of National Defence when that body was organized. In carrying out this work, the general membership of this Society, among others, participated.

Study of the possible domestic supply of nitrates and nitric acid, followed by recommendations which, together with other influences, ultimately led to an appropriation by Congress of $20 000 000 for the purpose of ensuring a domestic supply of nitric acid to the Government such as would be adequate for its requirements in time of war.

An investigation into the future needs of the Navy for fuel oil, with special reference to available supply and oil lands withdrawn from entry by the Government for Naval use, with recommendations that have had an important influence on legislation which has been pending in relation to oil land reserves.

Many other investigations and reports have been made. The following quotations from the report of the Secretary of the Navy for 1917 show his appreciation of the Board's services:

"The Naval Consulting Board has been found very useful, not only in assisting in the solution of military problems, but in dealing with the immense flood of inventions and ideas submitted to the department from the country at large. It is true that a majority of these are not found of practical value, but it is a fact that practically all of them are submitted with the patriotic motive of helping win the war, and the department has felt that they are all entitled to serious and appreciative consideration. * * *

"During the year the work of this Board, organized and approved by Congress in 1915, has increased very materially in importance and volume, its meetings have been frequent and the work of its individual members has been such in some cases as to occupy almost their entire time in the service of the Government.

"Some time before the active entry of this country into war the board called a special meeting to which were invited some 50 of the leading scientists and industrial managers, whose special study fitted them to advise on the methods of meeting the submarine problem. Plans were immediately made to investigate every field to develop a means of preventing destruction of vessels and of defeating the U-boat. The investigation was divided according to the experience of the different members and associated scientists and with the co-operation and valuable assistance of the various manufacturing companies interested a highly developed system of teamwork has been attained and results accomplished not dreamed of at the beginning of the war.

"The services of the Board were offered to the Council of National Defense and accepted by that body for the investigation of all inventions submitted. Its services were also accepted by the War Department in an advisory capacity.

"Valuable assistance has been rendered merchant shipping by the board's activities. Through its initiative, counsel and work the United States Shipping Board formed its ship-protection committee, taking over the study of the protection of merchant ships, and to this committee was detailed one of the Consulting Board's most experienced members qualified in shipbuilding and with sea experience. In this field the board's work has resulted in materially reducing the shipping risk, with a consequent lowering of marine insurance rates.

"Not the least result of its work has been the stimulation of interest, in the problems brought up by the war, throughout the country by the general invitation to submit ideas for investigation. Early in the calendar year 1917 this interest manifested itself in the receipt of thousands of ideas weekly, and to care for this the department's connecting office has been greatly enlarged, the office of the board in New York has been organized on a working basis with a large force, and the whole movement has received the approval and hearty assistance of the great national engineering societies. The president of the board, Mr. Thomas A. Edison, has been giving his entire time to the work of the board in the service of his country, and has called to his assistance a capable staff who are working diligently upon naval problems.

"With war conditions increasing the need for labor and building materials, it was believed to be a wise policy to defer for a time the building of the new experimental and research laboratory. Such experiments as have been warranted have been made in private laboratories generously offered and at the Bureau of Standards. The need for this establishment, however, is more clearly shown than ever, and its support is urgently advised.

"The valuable results obtained by the work of this board are of too confidential a nature to make them the subject of a public document. The members have given freely of their time and scientific ability to the service of the Nation and have earned the gratitude of all who know their unselfish and patriotic service. I wish to express my sense of obligation for the cheerful co-operation, wise counsel, loyal devotion, and personal sacrifice which have characterized the membership of the board of distinguished civilians who responded, long before war was declared, to the selective draft with all the enthusiasm and efficiency of youthful volunteers."

Much of the most valuable work of the board has been the contributions of its individual members to the development of various offensive and defensive devices which are playing an important part to-day, and which will play a still greater part during the coming year. Publicity cannot, for obvious reasons, be given to their work, but when, if ever, the inside history of the activities of the Board and its members is published, it will be realized that they have given freely, and at much personal sacrifice, to the country's service.

A. M. HUNT,
ALFRED CRAVEN.

JAN. 10TH, 1918.

The Catskill Water Supply Celebration, November 14th, 1917.

A meeting to signalize the completion of the Catskill Water Supply was held in the Engineering Societies Building, on the evening of November 14th, 1917, under the auspices of the United Engineering Society, the American Society of Civil Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, about 1 100 being present.

George H. Pegram, President of the American Society of Civil Engineers, presided, the Committee in charge of the meeting consisting of Chas. Warren Hunt, Chairman, Calvin W. Rice, Samuel Sheldon, and E. Gybbon Spilsbury.

In introducing the first speaker of the evening, the Hon. John Purroy Mitchel, Mayor of the City of New York, Mr. Pegram stated that, in his opinion, the completion of the Catskill Water Supply marked the greatest engineering achievement of our time.

Mr. Mitchel described briefly the first steps toward a new water supply for the City under Mayor McClellan, and the organization of the Board of Water Supply, paying tribute to its efficiency and ability, as shown in its selection of such men as J. Waldo Smith, Chief Engineer, Merritt H. Smith, Robert Ridgway, Carleton E. Davis (all Members, Am. Soc. C. E.), and others who held posts of responsibility under it, and making due acknowledgment in behalf of the City for the service rendered by them. Mr. Mitchel also stated that the splendid work of engineers, generally, for City, State, or Nation, had come to be greatly appreciated, mentioning especially the work of those who have been engaged in the service of the City of New York during his administration and of those who had answered the call for service under the United States Government in the present crisis.

Mr. Pegram, after explaining the unavoidable absence of Gen. Goethals, who had expected to address the meeting, introduced Charles Strauss, President of the Board of Water Supply.

Mr. Strauss also eulogized the work of the engineers and men engaged on the new water supply, and stated that the two outstanding facts which make it a civic lesson, are its successful completion one year before the estimated time, and that the cost was about $7 000 000 less than the original estimate.

Mr. Pegram then introduced Alfred D. Flinn, M. Am. Soc. C. E., Deputy Chief Engineer of the Board of Water Supply, who described, with the aid of lantern slides, the source of the Catskill Water Supply, the works for collecting the water and conducting it to the city, and some of the engineering problems involved.

Mr. J. Waldo Smith, when called on, spoke of the co-operation of the Commissioners and the loyalty and good-fellowship of the whole working force, as the chief factors in the successful prosecution of the work.

Engineering Council

A meeting of the Engineering Council was held on December 6th, 1917, in the Board Room of the American Society of Civil Engineers, Dr. I. N. Hollis, Chairman, presiding; and present, also, Messrs. Baker, Buck, Carle, Channing, Greene, Herschel, Humphreys, Hunt, Jacobus, Jennings, Moore, Swain, and Townley of the Council; also, by invitation, Messrs. George J. Foran and D. W. Brunton; also, Dr. William McClellan, Director of the Intercollegiate Intelligence Bureau; also, Mr. W. F. M. Goss, of a special committee of the American Society of Mechanical Engineers; also, a delegation of some fifteen members of the Society for the Promotion of Engineering Education.

The resignation of Mr. Calvert Townley, who had acted as Secretary since the organization of the Engineering Council, was accepted with expressions of appreciation for his efficient service.

The report of the Committee appointed to recommend a candidate for Permanent Secretary of the Engineering Council and also of the United Engineering Society and the Engineering Foundation, was presented, and Alfred D. Flinn, M. Am. Soc. C. E., was unanimously elected to the office, his term to begin January 1st, 1918.

A report of the Committee on Rules, providing for the admission of additional engineering and technical societies, was adopted.

The matter of the administration of the National Selective Draft, with respect to students in engineering schools, having been recommended to the consideration of the Engineering Council, the following resolution was adopted, and copies were ordered to be sent by telegram and letter to the Hon. Newton D. Baker, Secretary of War, and to Gen. Enoch F. Crowder, Provost Marshal:

"*Resolved*, The Engineering Council, representing the American Society of Civil Engineers, The American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, recognizing the serious responsibility of the Engineer for the successful prosecution of the war, in the many branches of the National service where highly trained Engineers are required, urges the importance, as a war measure, of maintaining unimpaired the Engineering strength of the Nation, for the successful prosecution of military operations, and for the support of sustaining industries.

"Since Schools of Engineering are the principal sources from which trained Engineers may be drawn, the Engineering Council urges that in the administration of the selective draft the Government should maintain these Schools in full operation, and should take such steps as will enable qualified Engineering students to continue their studies to graduation, if possible, and, in any event, until necessity demands their call for active service.

"This recommendation is made for the sole purpose of insuring the continuous supply of trained Engineers for the future service of the Nation."

D. W. Brunton, Chairman of the War Committee of Technical Societies, Dr. William McClellan, Director of the Intercollegiate Intelligence Bureau, and George J. Foran, Chairman of the American Engineering Service, respectively addressed the meeting on the work of these committees.

Welcome of the American Society of Civil Engineers into the Fraternity of the Founder Societies

On December 7th, 1917, at a meeting held in the Auditorium of the Engineering Societies Building, under the auspices of the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, the American Society of Civil Engineers was welcomed to the fraternity of the Founder Societies. At one o'clock on that day the President and Board of Direction of the Society were entertained at luncheon, and in the evening formal exercises were held.

Charles F. Rand, President of the United Engineering Society, presided. Gano Dunn, M. Am. Soc. C. E., representing the American Institute of Electrical Engineers, addressed the meeting. Ira N. Hollis, Past-President, American Society of Mechanical Engineers, spoke as a representative of that Society. Dr. Rossiter W. Raymond, Secretary Emeritus of the American Institute of Mining Engineers, addressed the meeting as a representative Mining Engineer. William L. Saunders, M. Am. Soc. C. E., was introduced by the chairman as not speaking for any particular Society, but for the Profession generally. George H. Pegram, President, Am. Soc. C. E., responded to the cordial words of welcome in behalf of this Society, and introduced George F. Swain, Past-President, Am. Soc. C. E., who spoke from the standpoint of the out-of-town members. Chas. Warren Hunt, Secretary, Am. Soc. C. E., was called upon by Mr. Rand to say a few words, and, as Vice-President of the United Engineering Society, to adjourn the meeting.

The new quarters of the Society were open for inspection, and were visited by a great many members of the Society and others.

Correspondence Relative to the Donation of the Use of the Society House to the United States Food Administration

The following correspondence, relative to the donation by the Society of the use of its House to the United States Food Administration, is published here for the information of the membership.

"December 17, 1917.

"Herbert Hoover, Esq.
"United States Food Administrator
"Washington, D. C.

"Dear Sir:—I am in receipt of your communications of December 1st and 12th, 1917, with regard to your acceptance of the offer of this Society to place the building which it owns, No. 220 West Fifty-seventh Street, New York City, at the disposal of the U. S. Food Administration.

"I understand that the building is to be used as headquarters for the activities of the Federal Food Board of the State of New York, and that Mr. Arthur Williams represents both the United States Food Administration and State Board, and is authorized to act for either in this matter.

"The Society is very glad to donate the use of this building to the Government for this very essential work, under as few conditions as possible. These conditions are as follows:

"(1) That all expenses incident to the occupancy of the building by the Food Administration, including Janitor and other attendants, heat, light, and water, insurance, and taxes, if any, will be assumed and paid by the Food Administration.

"(2) That the Janitor, or other person employed by the Food Administration to take care of the property, shall be satisfactory to, and under the control of, this Society so far as its interests are concerned, although paid by the Food Administration.

"(3) That at any time the American Society of Civil Engineers may desire to take the building over, it will be promptly vacated by the Food Administration. It is understood that this is intended merely as a safeguard to the Society in the event of its securing a satisfactory offer for the property, either for sale or for lease, and that ten days will be deemed a sufficient notice.

"(4) That upon the termination for any cause of the occupancy of the building by the Food Administration it will be turned over to the owners in as good condition as when their occupancy began.

"(5) That no alteration of the building, or any of its appurtenances, shall be made without written consent of the American Society of Civil Engineers.

"Permit me to say that it is the desire of this Society to do everything possible to aid your Board, and it will give the undersigned pleasure at any time to do everything in his power to carry out this desire. "Yours respectfully,

"CHAS. WARREN HUNT,
"Secretary."

"WASHINGTON, D. C.
"December 19, 1917.

"DR. CHARLES WARREN HUNT, *Secretary,*
"American Society of Civil Engineers,
"33 West 39th Street,
"New York City.

"Dear Dr. Hunt:—Many thanks for your personal and formal letters of December 17th.

"I note the conditions set forth in your formal letter regarding the donation of your building, No. 220 West 57th Street, to the New York Federal Food Board and herewith accept these conditions on behalf of the United States Food Administration. I am returning to you carbon copy of your letter of December 17th, to which I refer.

"Let me again express to you and the Society my keen appreciation of the generosity which you show in the donation to us of your building. It is additional evidence of the splendid generous support contributed by engineers in this war. I am sure that the use of this building will benefit greatly the work of the Federal Food Board.

"With kind regard, I am

"Yours faithfully,

"HERBERT HOOVER."

Conference of Technical Societies and Technical War Committees

A conference of the representatives of the technical societies and the technical war committees of the United States was held, at the call of Mr. Ambrose Swasey, at the Bureau of Standards, Washington, D. C., on October 26th, 1917.

There were present, Col. J. J. Carty, in the chair, representing the Executive Committee of the National Research Council, Calvin W. Rice, Secretary, representing the United Engineering Society; and present, also, Messrs. Chas. Warren Hunt, representing the United Engineering Society and the Engineering Foundation; H. C. Dickinson, representing the Bureau of Standards and the American Society of Refrigerating Engineers; Gano Dunn and S. W. Stratton, representing the Engineering Committee of the National Research Council; M. I. Pupin and W. F. Durand, representing the National Advisory Committee for Aeronautics; L. T. Robinson and N. A. Carle, representing the American Institute of Electrical Engineers; Ambrose Swasey and John H. Barr, representing the American Society of Mechanical Engineers; George

C. Stone, representing the American Institute of Mining Engineers; S. S. Voorhees, representing the American Society for Testing Materials; F. C. Diffin and George K. Burges, representing the International Aircraft Standards Board; Arthur A. Noyes, representing the Executive Committee of the National Research Council; W. R. Addicks and Alfred E. Forstall, representing the American Gas Institute; Comfort A. Adams, representing the General Engineering Committee of the Advisory Commission of the Council of National Defence and the American Engineering Standard Organization Committee; William McClellan, representing the Intercollegiate Intelligence Bureau and the Professional Service Bureau; D. W. Brunton, representing the American Institute of Mining Engineers and the War Committee of Technical Societies of the Engineering Council; R. A. Millikan, representing the National Research Council; George J. Foran, representing the American Society of Mechanical Engineers and the American Engineering Service Committee of the Engineering Council; John W. Lieb, representing the National Committee on Gas and Electric Service of the Council of National Defence, and the President of the Association of Edison Illuminating Companies; L. B. Stillwell and F. A. Molitor, representing the American Institute of Consulting Engineers; J. V. Davies and Alfred D. Flinn, representing the American Society of Civil Engineers; Walter F. Wells, representing the National Electric Light Association; William B. Stout and Coker F. Clarkson, representing the Society of Automotive Engineers; Henry Torrance, representing the American Society of Refrigerating Engineers; Charles Whiting Baker and H. W. Buck, representing the Engineering Council; Henry E. Crampton and Charles J. Tilden, representing the Engineering Committee of the Advisory Commission of the Council of National Defence; and James Boyle, representing the War Committee of Technical Societies of the Engineering Council.

A general statement of the activities of the Research Council, Engineering Committee of the Advisory Commission of the Council of National Defence, National Committee of Gas and Electric Service, Engineering Council, Aircraft Production Board, and Aircraft Standardization, was presented by Mr. Gano Dunn.

On motion, duly seconded, it was decided to call on the representatives of each organization present to state the general nature of its work and its official or unofficial connection with the Government.

Professor Comfort A. Adams, Chairman of the American Engineering Standards Organization Committee, reported the formation, at the request of the Navy Department, of a special committee to advise as to specifications for insulated wires for battleships.

The formation of the Engineering Council and its purpose to represent all engineering societies in matters of common interest, were explained by Messrs. H. W. Buck and Charles Whiting Baker.

Mr. George J. Foran, representing the American Engineering Service Committee of the Engineering Council, stated that the Committee had been appointed by the Engineering Council, and that it had prepared and cross-referenced a catalogue of the membership of three engineering societies, with the qualifications of each member.

The War Committee of Technical Societies, as reported by Mr. D. W. Brunton, was appointed by the Engineering Council to encourage and consider inventions presented by members of engineering societies and by others.

J. W. Lieb, M. Am. Soc. C. E., reported on the activities of the Committee on Gas and Electric Service, stating that it had furnished experts and expert advice on inspection for the Naval Advisory Board, the Priority Board, the Fuel Administrator, the Quartermaster Department, the Provost Marshal General, the Aircraft Production Board, the Emergency Fleet Corporation, and the Signal Corps.

For the General Engineering Committee of the Advisory Commission of the Council of National Defence, Professor Adams stated that the Committee was chiefly occupied with the development of anchor chain manufacture and the application of electrical spot welding to shipbuilding as a substitute for riveting.

Dr. William McClellan reported that the Intercollegiate Intelligence Bureau, representing 200 colleges in the United States, receives calls for men and has distributed men to adjutants in the various schools. In addition, in co-operation with the Engineering Council, the Bureau had formed the Professional Service Bureau to furnish specially trained men for all kinds of professional service. It is also interested in the Public Service Reserve attached to the U. S. Department of Labor, to provide men for war services of every kind.

Mr. F. C. Diffin, for the International Aircraft Standards Board, reported that it was composed of representatives of Great Britain, France, Italy, and the United States, to prepare specifications for standards of raw materials in the aircraft industry and of aircraft details. Mr. Diffin pointed out the need of giving publicity to the work of this Board.

For the Aeronautical Committee (the Executive Committee of the Advisory Commission on Aeronautics) of the National Research Council, Dr. W. F. Durand, reported that it is the duty of this Committee to supervise and direct the scientific study of problems of flight, with a view to their practical solution, etc., and to direct and conduct laboratory researches and experiments in aeronautics. Research problems relative to aerodynamics, materials of aircraft construction, power plants, and aircraft armament, equipment, etc., are being solved under the direction of this Committee, which also acts as an Advisory Board on inventions pertaining to aircraft, and makes recommendations to the Government Bureaus on those submitted. The Committee is also endeavoring to secure uniformity of patents, insurance for aviators, aircraft insurance, and the question of aerial mail routes.

Mr. C. F. Clarkson reported for the Society of Automotive Engineers that it was engaged on the standardization and design of Liberty aeronautical engines, military trucks, motor cycles, tractors for farm work, and military tractors.

On motion, duly seconded, it was decided that a Committee on Civilian Engineering Activities be appointed to confer with the Engineering Council, Councils of Government, and bodies of other civilian organizations, with a view to rendering most effective the work of civilian engineers.

On motion, duly seconded, a vote of thanks was extended to Dr. Stratton, of the Bureau of Standards, for assistance given, and a rising vote of thanks was extended to Mr. Swasey for calling the conference.

ANNOUNCEMENTS

The Reading Room of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

February 6th, 1918.—8.30 P. M.—This will be a regular business meeting. A paper by F. W. Gardiner and S. Johannesson, Members, Am. Soc. C. E., entitled, "Manhattan Elevated Railway Improvements", will be presented for discussion.

This paper was printed in *Proceedings* for December, 1917.

February 20th, 1918.—8.30 P. M.—A meeting will be held on this evening as usual, and announcement of the speaker and subject will be made later.

March 6th, 1918.—8.30 P. M.—A regular business meeting will be held, and a paper by Floyd A. Nagler, Jun. Am. Soc. C. E., entitled "Verification of the Bazin Weir Formula by Hydro-Chemical Gaugings", will be presented for discussion.

This paper is printed in this number of *Proceedings.*

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

It sometimes happens that references are found which are not readily accessible to the person for whom the search is made. In that case the material may be reproduced by photography, and this can be done for members at the cost of the work to the Society, which is small. This method is particularly useful when there are drawings or figures in the text which would be very expensive to reproduce by hand.

A list of 989 bibliographies made in the Library, giving the cost of each, was published in Vol. LXXX of *Transactions.*

Since October 1st, 1916, the Library of the American Society of Civil Engineers has ceased to exist, as such, having been merged with the Libraries of the Mining, Mechanical, and Electrical Engineers, and become a part of the Library of the United Engineering Society. There were 67 000 accessions, which were not duplicates, turned over to that Library.

Hereafter, therefore, requests for searches should be addressed to the Librarian, Engineering Societies Library, 29 West 39th Street, New York City.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings.*

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion will be published as heretofore in *Proceedings,* and set down for presentation to a future meeting of the Society, and on these oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which from their mathematical or technical nature, in the opinion of the Committee, are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions only will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions.*

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 35 of the Year Book for 1917.

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association, Organized 1905.

Jerome Newman, President; Nathan A. Bowers, Secretary-Treasurer, 502 Rialto Building, San Francisco, Cal.

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Palace Hotel, on the third Tuesday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at noon, every Wednesday, at the Engineers' Club, 57 Post Street, where special tables are reserved for members and guests of the Association.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

Colorado Association, Organized 1908.

Robert Follansbee, President; L. R. Hinman, Secretary-Treasurer, 1400 West Colfax Avenue, Denver, Colo.

The meetings of the Colorado Association of Members of the American Society of Civil Engineers (Denver, Colo.) are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesdays at 12.30 P. M., at Daniel's and Fisher's.

Visiting members are urged to attend the meetings and luncheons.

(Abstract of Minutes of Meeting)

November 10th, 1917.—The meeting was called to order at the Denver Athletic Club; President Follansbee in the chair; L. R. Hinman, Secretary; and present, also, 12 members.

The minutes of the meetings of September 8th and October 6th, 1917, were read and approved.

A letter from the Denver Motor Club, together with a report from the Joint Committee appointed by the Motor Club, the Association, and other organizations, to investigate the condition of the roads surrounding Denver, was read by the Secretary, and announcement was made that Mr. Hinman who had been appointed to represent the Association on the Joint Committee had resigned and that Mr. Thomas W. Jaycox had agreed to take his place. The work of the Joint Committee was outlined by Mr. Jaycox, and, on motion, duly seconded, the Secretary was authorized to write to Mr. Bishop, who represented the Motor Club and who was instrumental in organizing the Joint Committee, thanking him for asking the Association to participate in the work.

A letter from Chas. Warren Hunt, Secretary of the Society, was read, calling the attention of the Association to a resolution passed by the Executive Committee of the Board of Direction relative to the War Revenue Act of 1917 as it affects engineers and professional men. On motion, duly seconded, the matter was referred to a committee of three, Messrs. M. S. Ketchum, Chairman, Charles W. Comstock and E. F. Vincent, with instructions to report at the December meeting.

The Secretary read a letter from the Connecticut Society of Civil Engineers relative to the establishment of Student Branches of the

Society. On motion, duly seconded, the matter was referred to Prof. Ketchum, as a committee of one, with instructions to report at the December meeting.

A paper by Mr. James Munn, Engineer of the United States Reclamation Service, entitled "The Construction of the Arrow Rock Dam", was read by the author, who illustrated his remarks with lantern slides. After the address, the subject was informally discussed by those present.

The appointment of Messrs. Thomas W. Jaycox, Chairman, A. N. Miller, and T. H. Olds, as the Entertainment Committee for the January meeting, was announced.

Adjourned.

Atlanta Association, Organized 1912.

B. M. Hall, President; W. C. Spiker, Secretary-Treasurer, 1408 Candler Building, Atlanta, Ga.

(Abstract of Minutes of Meeting)

August 31st, 1917.—The meeting was called to order at the Hotel Ansley; Vice-President Kriegshaber in the chair; T. P. Branch, Secretary; and present, also, 7 members.

The following officers were elected: President, B. M. Hall; Vice-President, T. P. Branch; and Secretary-Treasurer, W. C. Spiker.

On motion, duly seconded, Messrs. A. V. Gude, E. K. Large, and B. M. Hall were appointed a committee to call on Col. Brown, of the 103d Engineers, at Camp Gordon, and secure the names of all members of the Society at the camp, in order that such members could be invited to be present at the meetings and luncheons of the Association.

The President appointed Messrs. V. H. Kriegshaber and T. P. Branch as representatives of the Association on the Affiliated Technical Society Board.

Adjourned.

Baltimore Association, Organized 1914.

Mason D. Pratt, President; Charles J. Tilden, Secretary-Treasurer, The Johns Hopkins University, Baltimore, Md.

Cleveland Association, Organized 1914.

W. J. Watson, President; George H. Tinker, Secretary-Treasurer, 516 Columbia Building, Cleveland, Ohio.

Detroit Association, Organized 1916.

T. A. Leisen, President; Clarence W. Hubbell, Secretary, 2348 Penobscot Building, Detroit, Mich.

The regular meetings of the Association are held on the second Friday of December, April, and October, the last being the Annual Meeting.

District of Columbia Association, Organized 1916.

A. P. Davis, President; John C. Hoyt, Secretary-Treasurer, U. S. Geological Survey, Washington, D. C.

Duluth Association, Organized 1917.

F. E. House, President; Walter G. Zimmermann, Secretary, Wolvin Building, Duluth, Minn.

The regular meetings of the Association are held at noon on the third Monday of each month (usually at the Kitchi Gamma Club), with luncheon, followed by a short business session and the reading of papers. Visiting members of the American Society of Civil Engineers can secure from the Secretary definite information relating to the meetings, at which they will be welcomed. The Annual Meeting is held on the third Monday in May.

(Abstract of Minutes of Meeting)

December 17th, 1917.—The meeting was called to order; Vice-President John H. Darling in the chair; H. C. Ash, acting as Secretary; and present, also, 17 members and 1 guest.

Mr. M. B. Benson, of the Lake Superior Electrical Company, addressed the meeting, describing the electric telemotor, a device for controlling the rudder of a ship from the pilot-house by electricity, the recording electric compass for recording the continuous changes of a ship's course, and the electric signal whistle combined with flashlight signals.

Adjourned.

Illinois Association, Organized 1916.

A. S. Baldwin, President; Edgar S. Nethercut, Secretary-Treasurer, 705 Michigan Ave., Evanston, Ill.

The regular meetings of the Association are held on the second Monday of March, June, September, and December, the last being the Annual Meeting. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary.

Louisiana Association, Organized 1914.

W. B. Gregory, President; Charles W. Okey, Secretary, Tulane University, New Orleans, La.

The regular meetings of the Association are held at The Cabildo, New Orleans, La., on the first Monday of January, April, July, and October.

Nebraska Association, Organized 1917.

Frank T. Darrow, President; Homer V. Knouse, Secretary-Treasurer, 115 City Hall, Omaha, Nebr.

Regular meetings of the Association are held on the first Saturday of each month, except July and August, and at such places as may be appointed from time to time by the Executive Committee. The Annual Meeting is held in Lincoln, Nebr., on the second Friday in January.

An "Engineers' Round Table" is reserved daily for luncheon, at Courtenay's Restaurant, 17th and Douglas Streets, Omaha, to which all engineers are invited. Visiting members of the Society are especially urged to communicate with the Secretary when in the city.

(Abstract of Minutes of Meeting)

December 8th, 1917.—Following an inspection trip to the Minne Lusa Pumping Station and the Laboratory and Alum Plant of the Metropolitan Water District of the City of Omaha, the meeting was called to order at the Laboratory at 8.00 P. M.; President Darrow in the chair; Homer V. Knouse, Secretary; and present, also, 21 members and guests.

The minutes of the meeting of November 10th, 1917, were read and approved.

An informal description of the system of the Metropolitan Water District, with particular reference to the Minne Lusa Pumping Station, was presented by George T. Prince, M. Am. Soc. C. E.

Mr. Andrew Jacobsen, Chief Chemist of the Water District, described the Alum Manufacturing Plant and the effect on operating costs of the various processes substituted, since Alum Cake had been in use, for commercial sulphate of alumina. Mr. Jacobsen also referred to the use of scrap iron with the alum solution to produce a basic coagulant.

The resolution adopted by the Executive Committee of the Board of Direction of the Society, relative to the War Revenue Act of 1917, was discussed by Messrs. Holdrege, Campen, Dobson, Mickey, and others.

Nominations for officers for 1918 were made as follows: For President, Messrs. Prince and Campen; for Senior Vice-President, Messrs. Holdrege and Mickey; for Junior Vice-President, Messrs. Hershey and Bruce; and for Secretary-Treasurer, Homer V. Knouse.

On motion, duly seconded, it was decided that the next meeting of the Association should be devoted to matters pertaining to the War, with particular reference to the part of the Engineer therein. Messrs. Mickey and Dobson were appointed a committee to take charge of the meeting.

Adjourned.

Northwestern Association, Organized 1914.

George L. Wilson, President; Ralph D. Thomas, Secretary, 508 South First Street, Minneapolis, Minn.

Philadelphia Association, Organized 1913.

Henry H. Quimby, President; C. W. Thorn, Secretary, 1313 South Broad Street, Philadelphia, Pa.

The regular meetings of the Association are held at the Engineers' Club of Philadelphia, 1317 Spruce Street, on the First Monday in January, April, and October, the last being the Annual Meeting.

Portland, Ore., Association, Organized 1913.

J. P. Newell, President; J. A. Currey, Secretary, 194 North 13th Street, Portland, Ore.

St. Louis Association, Organized 1888 (1914).

J. A. Ockerson, President; C. M. Daily, Secretary-Treasurer, 34 East Grand Avenue, St. Louis, Mo.

The Annual Meeting of the Association is held on the fourth Monday in November in the Auditorium of the Engineers Club of St. Louis. The time and place of other meetings are not fixed, but this information will be furnished on application to the Secretary.

San Diego Association, Organized 1915.

N. B. Kellogg, President; J. R. Comly, Secretary-Treasurer, 4105 Falcon Street, San Diego, Cal.

(Abstract of Minutes of Meeting)

December 14th, 1917.—The Annual Meeting was called to order; President W. J. Gough in the chair; J. R. Comly, Secretary.

The following officers were elected for 1918: President, N. B. Kellogg; Vice-President, George Cromwell; and Secretary-Treasurer, J. R. Comly.

Discussion of the resolution of the Executive Committee of the Board of Direction of the Society, relative to the War Revenue Act, was postponed, to be taken up at a special meeting of the Association.

The following members of the Association were reported as having received commissions in the Engineer Officers' Reserve Corps: F. M. Billings, J. F. Covert, J. R. Comly, George Cromwell, W. J. Gough, L. R. Johnson, and W. S. Post.

Mr. Cromwell tendered his resignation as a member of the Association, but action thereon was postponed.

Adjourned.

Seattle Association, Organized 1913.

Joseph Jacobs, President; Carl H. Reeves, Secretary-Treasurer, 444 Henry Building, Seattle, Wash.

The regular meetings of the Association are held at 12.15 P. M., on the last Monday of each month, at The Frye Hotel.

Southern California Association, Organized 1914.

H. Hawgood, President; H. W. Dennis, Secretary, 329 San Fernando Building, Los Angeles, Cal.

The Southern California Association of Members of the American Society of Civil Engineers (Los Angeles, Cal.) holds regular bimonthly meetings with banquet, at Hotel Clark, on the second Wednesday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M. every Wednesday, and the place of meeting may be ascertained from the Secretary.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in Los Angeles, and any such member will be gladly welcomed as a guest at any of the meetings or luncheons.

Spokane Association, Organized 1914.

J. C. Ralston, President; B. J. Garnett, Secretary, City Hall, Spokane, Wash.

The regular meetings of the Association are held on the second Friday of each month, except July and August. The hour and place

of meeting are not fixed, but this information will be furnished on application to the Secretary.

Visiting members are invited to attend the meetings and luncheons.

Texas Association, Organized 1913.

John B. Hawley, President; J. F. Witt, Secretary, Dallas, Tex.

Utah Association, Organized 1916.

George L. Swendsen, President; H. S. Kleinschmidt, Secretary-Treasurer, 306 Dooly Building, Salt Lake City, Utah.

The Annual Meeting of the Association is held on the first Wednesday in April. The time of other meetings is not fixed, but this information will be furnished on application to the Secretary.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms, and at all meetings:

American Institute of Electrical Engineers, 25 West Thirty-ninth Street, New York City.

American Institute of Mining Engineers, 25 West Thirty-ninth Street, New York City.

American Society of Mechanical Engineers, 25 West Thirty-ninth Street, New York City.

Associacão dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 176 Mansfield Street, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, Public Library, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Detroit Engineering Society, 46 Grand River Avenue, West, Detroit, Mich.

Engineering Association of Nashville, Commercial Club Building, Nashville, Tenn.

Engineering Societies Club of Hawaii, E. F. Cykler, Secretary, Honolulu, Hawaii.

Engineers and Architects Club of Louisville, 1412 Starks Building, Louisville, Ky.

Engineers' Club of Baltimore, 6 West Eager Street, Baltimore, Md.

Engineers' Club of Kansas City, E. B. Murray, Secretary, 920 Walnut Street, Kansas City, Mo.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Club of Trenton, Trent Theatre Building, 12 North Warren Street, Trenton, N. J.

Engineers' Society of Northeastern Pennsylvania, 415 Washington Avenue, Scranton, Pa.

Engineers' Society of Pennsylvania, 31 South Front Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 568 Union Arcade Building, Pittsburgh, Pa.

Florida Engineering Society, J. R. Benton, Secretary, Gainesville, Fla.

Institute of Marine Engineers, The Minories, Tower Hill, London, E., England.

Institution of Civil Engineers, Great George Street, Westminster, S. W., London, England.

Institution of Engineers of the River Plate, Calle 25 de Mayo 195, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, State Museum Building, Chartres and St. Ann Streets, New Orleans, La.

Memphis Engineers' Club, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Montana Society of Engineers, Butte, Mont.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Oregon Society of Civil Engineers, Portland, Ore.

Pacific Northwest Society of Engineers, 803 Central Building, Seattle, Wash.

Rochester Engineering Society, Rochester, N. Y.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Societe des Ingenieurs Civils de France, 19 rue Blanche, Paris, France.

Society of Engineers, 17 Victoria Street, Westminster, S. W., London, England.

Southwestern Society of Engineers, C. E. Barglebaugh, Secretary, 703 First National Bank Building, El Paso, Tex.

Svenska Teknologforeningen, Brunkebergstorg 18, Stockholm, Sweden.

Tekniske Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Vermont Society of Engineers, George A. Reed, Secretary, Montpelier, Vt.

Western Society of Engineers, 1735 Monadnock Block, Chicago, Ill.

ANNUAL REPORT OF THE BOARD OF DIRECTION FOR THE YEAR ENDING DECEMBER 31st, 1917.

In compliance with the Constitution, the Board of Direction presents its report for the year ending December 31st, 1917.

MEMBERSHIP

The changes in membership are shown in the following table:

	Jan. 1st, 1917.			Jan. 1st, 1918.			Losses.				Additions.		Totals.		
	Resident.	Non-Resident.	Total.	Resident.	Non-Resident.	Total.	Transfer.	Resignation.	Dropped.	Death.	Transfer.	Election.	Loss.	Gain.	Increase.
Honorary Members.	.....	4	4	.....	3	3	....	..	..	1	.....	.....	1	....	§1
Corresponding "	.....	1	1	.....	1	1	....	..	..	..	.....	.....	....	....	....
Members	681	2 833	3 514	711	2 946	3 657	....	7	17	44	*126	‡85	68	211	143
Associate Members.	625	3 142	3 767	633	3 467	4 100	126	32	37	11	†123	‖416	206	539	333
Associates	66	102	168	58	107	165	2	2	1	3	.....	¶5	8	5	§3
Juniors	132	593	725	111	542	653	121	10	43	..	.....	**102	174	102	§72
Fellows	5	8	13	4	7	11	....	..	..	2	.....	.....	2	....	§2
Totals	1 509	6 683	8 192	1 517	7 073	8 590	249	51	98	61	249	608	459	857	398

* 126 Associate Members.
† 2 Associates, 121 Juniors.
‡ 2 Reinstatements.
‖ 4 Reinstatements.
¶ 1 Reinstatement.
** 1 Reinstatement.
§ Decrease.

The net increase in membership for the year was 398; total number of applications received 956: 693 for admission and 263 for transfer.

The losses by death during the year number 61 and are as follows:

Honorary Members (1): William Douglas Pickett.

Members (44): John Ferris Alden, Daniel Marshall Andrews, William Harry Arnold, William Sinclair Bacot, William Henry Baldwin, Arthur Beardsley, Van Brunt Bergen, Daniel Wheeler Bowman, John Griffiths Brown, Hiram Martin Chittenden, Otis Francis Clapp, Elmer Ellsworth Colby, Lyman Edgar Cooley, Charles Lee Crandall, Andrew Chase Cunningham, Joseph Phineas Davis, Edmund Hazen Drury, Richard Evans, Frank Firmstone, Harry Madera Gould, James Walter Grimshaw, William Oswald Henderer, Henry Augustus Herrick, Joseph Hobson, William Henry Hunter, James Edgar Jenkins, William Stone Johnson, Walter Katté, Eugene Castner Lewis, Franklin Buchanan Locke, Alexander William MacCallum, Thomas Chalmers McCollom, William Walter Marr, Sir Hiram Stevens Maxim, Harvey

Cooper Miller, Stanley Alfred Miller, David Simson, Richard Edward Speakman, David Wendel Spence, Henry Gordon Stott, John Edward Swanker, Erle Leroy Veuve, Isaac Wayne von Leer, Edward Thomas Wright.

Associate Members (11): Harold Davis, John Hatfield Frazee, Howard Arnold Greene, Joel Manning Howard, William Herbert Hyde, Lora Walter Miller, George Alexander Hutchings Mould, William Stuart Smith, Samuel Forsythe Thomson, Louis Wachtel, David Miller White.

Associates (3): George Henry Frost, Lewis Roberts Pomeroy, Ernest Leslie Ransome.

Fellows (2): Charles Marvin Everest, Nelson James Welton.

LIBRARY

At the time of the last Report of the Board, December 31st, 1916, the Library, so far as its management was concerned, had been turned over to the Engineering Societies Library, although it had not been moved to the Thirty-ninth Street Building. The work of preparation for moving the books had been finished.

The movement of the 67 000 volumes, of which there were no duplicates in the Engineering Societies Library, was completed during February, under the supervision of Dr. Hunt. They were arranged temporarily on the shelves in the Thirty-ninth Street Building in the same order as in the Fifty-seventh Street House, and were inaccessible for use for only a few days. Since that time they have been left in the same condition, that is to say, they are available for use in the Engineering Societies Library exactly as they had been heretofore in our old House.

There were about 22 000 books and pamphlets in the Library of the Society which were duplicated in the Engineering Societies Library, and a number of suggestions as to the disposition of these books were made. After careful consideration of all the proposals, most of which contemplated breaking up the collection and disposing of parts of it to various libraries, it was decided to donate all these books to the Cleveland Association of Members, on the understanding that the collection would be kept intact and would form the nucleus for an Engineering library in Cleveland. In July, 1917, this action was carried out. The books were transferred to the custody of the Cleveland Association of Members, and are now on the shelves of the Cleveland Public Library, which consented to become the custodian of them.

The book stacks belonging to this Society were dismantled and donated to the United Engineering Society, and erected in the new stack room on the fourteenth floor, immediately below the new quarters of the Society.

Our new Reading Room where about 400 current periodicals are kept, will be in close touch with the Engineering Societies Library, and is intended for use by the membership and others, practically in the same way as was the Reading Room in Fifty-seventh Street in connection with the Library of this Society.

By resolution of your Board, the ownership of that portion of the Society's Library which was moved to the Engineering Societies Library, was formally tendered to the United Engineering Society, but up to the present time, no formal acceptance of the gift has been received. On April 1st, 1917, Mr. Harrison W. Craver was appointed Director of the Engineering Societies Library, and at once assumed his duties. It will be noted that book notices of important accessions to the united library have been published continuously in our *Proceedings.*

COMMITTEES

There are at present six Special Committees made up of members appointed to report on Engineering subjects. Two of these have written final reports, which will be presented to the Annual Meeting.

Messrs. William H. Burr, J. H. Gregory, and H. N. Latey, were appointed to represent the Society on a Joint Committee on Organization of an American Engineering Standards Committee, the other Societies represented being the American Institute of Mining Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, and the American Society for Testing Materials. This Committee reported,* and the same representatives of this Society have been appointed to serve on the permanent committee therein recommended.

Messrs. Clemens Herschel, Benjamin F. Groat, and N. A. Carle, were appointed as the representatives of this Society on a Joint Committee with other Societies to report on a Code for the Testing of Water Wheels.

PUBLICATIONS

During the year, ten numbers of *Proceedings* and one Year Book have been issued.

In *Proceedings* the list of references to current engineering literature has been continued, and has covered 129 pages and contained 5 016 classified references to 109 periodicals.

The stock of the various publications of the Society, kept on hand for the convenience of members and others, now amounts to 158 014 copies, the cost of which to the Society, for paper and press work only, has been $23 938.14.

During the year 5 653 volumes of *Transactions* have been bound for members and others in standard half-morocco and cloth bindings.

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* *Proceedings*, Vol. XLIII, p. 414 (August, 1917).

Summary of Publications for 1917.

	Issues.	Average editions.	Total pages.	Plates.	Cuts.
Proceedings (monthly numbers)..	10	8 550	3 432	61	645
Year Book	1	9 100	371	1	...
Total	11	....	3 803	62	645

The cost of publications has been:

For Paper, Printing, etc., *Proceedings*...........	$24 319.65
For Plates and Cuts............................	3 703.97
For Boxes, Mailing Lists, Copyright, and Sundry Expenses	584.56
For 15 675 Extra Copies of Papers and Memoirs...	1 522.00
For Year Book............................	3 566.79
Total..................................	$33 696.97
Deduct amount received from sale of publications..	3 879.43
Net expenditure for publications for 1917....	$29 817.54

The volume of *Transactions* (Vol. LXXXI) has not as yet been issued to the membership, due to several causes. One of these was that it was not possible to close up the Final Report of one of the Special Committees which had to be issued in this volume of *Transactions,* and the other was that the movement of the Society Headquarters made it very difficult to carry on all the work of the Society in the usual systematic manner. The volume is nearly all printed, however, and will be issued as soon as possible. On account of this fact the total cost of publications this year is not comparable with similar figures of previous years.

As nearly as can be stated at the present time, the statistics of Vol. LXXXI of *Transactions* will be about as follows:

The edition is 8 700, and the volume will contain 1 874 pages, with 17 inserted plates, and 363 cuts; and its approximate cost, for purposes of comparison with previous years' expenditures for publications, will be $13 000.

MEETINGS

Twenty-three meetings were held during the year. The Business Meeting of the Annual Meeting of 1917 was held in the Engineering Societies Building by invitation of the United Engineering Society, this Society at that time not having moved its Headquarters. The meetings of April 4th, November 5th, November 21st, December 5th, and December 19th, were also held in the Thirty-ninth Street Building. All other meetings during the year were held at the Fifty-seventh Street House.

At these meetings there were presented 20 formal papers, 9 of which were illustrated with lantern slides, 4 lectures, 2 of which were illustrated with lantern slides, and 1 informal discussion. There were also four papers published which were not presented for discussion at any meeting of the Society. The number of members and others who took part in the preparation or discussion of these papers and lectures was 281.

The Forty-ninth Annual Convention, which was to have been held at St. Paul and Minneapolis, Minn., on June 12th to 15th, 1917, was abandoned on account of the war.

The total attendance at the 23 meetings was about 4 320. The registered attendance at the Annual Meeting was 776, but there were many guests present at all these meetings and also members who failed to register.

In addition to these meetings, the Society has participated in joint meetings with other organizations as follows:

On the evening of May 10th, 1917, in the auditorium of the Engineering Societies Building, the John Fritz Medal for 1917 was awarded to Professor Henry M. Howe for his "Investigations in Metallurgy and Especially in the Metallography of Iron and Steel."

On November 14th, 1917, there was held in the Auditorium a Joint Meeting of the Founder Societies, at which about 1 100 persons were present, signalizing the completion of the Catskill Water Supply. President Pegram presided, and addresses were made by Hon. John Purroy Mitchel, Mayor of the City of New York, Charles Strauss, President, Board of Water Supply, and J. Waldo Smith, M. Am. Soc. C. E., Chief Engineer. Alfred D. Flinn, M. Am. Soc. C. E., Deputy Chief Engineer, described this great work, illustrating his remarks with lantern slides.

On December 7th, 1917, the Society was formally welcomed as one of the Founder Societies by the other three Founders, the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers. At one o'clock on that day the President and Board of Direction of the Society were entertained at luncheon, and in the evening, in the Auditorium of the Engineering Societies Building, formal exercises were held. Chas. F. Rand, President, U. E. S., presided. Gano Dunn, M. Am. Soc. C. E., representing the American Institute of Electrical Engineers, addressed the meeting. Ira N. Hollis, Past-President, American Society of Mechanical Engineers, spoke as a representative of that Society. Dr. Rossiter W. Raymond, Secretary Emeritus of the American Institute of Mining Engineers, addressed the meeting as a representative Mining Engineer. William L. Saunders, M. Am. Soc. C. E., was introduced by the Chairman as not speaking for any particular Society, but for the Profession generally. George H. Pegram.

President, Am. Soc. C. E., responded to the cordial words of welcome in behalf of this Society, and called on Past-President George F. Swain to speak from the standpoint of the out-of-town members. Chas. Warren Hunt, Secretary, American Society of Civil Engineers, was called upon by Mr. Rand to say a few words, and as Vice-President of the United Engineering Society to adjourn the meeting.

The new quarters of the Society were open for inspection during the evening and were visited by a great many members of the Society, and others.

MEDALS AND PRIZES

For the year ending with July, 1916, prizes were awarded as follows:

The Norman Medal to J. A. L. Waddell, M. Am. Soc. C. E., for his paper entitled, "The Possibilities in Bridge Construction by the Use of High-Alloy Steels."

The J. James R. Croes Medal to C. E. Smith, M. Am. Soc. C. E., for his paper entitled "History of Little Rock Junction Railway Bridge, of the St. Louis, Iron Mountain and Southern Railway Company, Over the Arkansas River at Little Rock, Arkansas, 1883-1914."

The Thomas Fitch Rowland Prize to E. L. Sayers and A. C. Polk, Members, Am. Soc. C. E., for their paper entitled, "The Lock 12 Development of the Alabama Power Company, Coosa River, Alabama."

The James Laurie Prize to William G. Grove, Esq. (now M. Am. Soc. C. E.), and Henry Taylor, Assoc. M. Am. Soc. C. E., for their paper entitled, "Reconstruction of the Norfolk and Western Railway Company's Bridge Over the Ohio River at Kenova, West Virginia."

The Collingwood Prize for Juniors to Harold Perrine, Jun. Am. Soc. C. E. (not now connected with the Society), and George E. Strehan, Jun. Am. Soc. C. E. (now Assoc. M. Am. Soc. C. E.), for their paper entitled. "Cinder Concrete Floor Construction Between Steel Beams."

CHANGE OF SOCIETY HEADQUARTERS

In the last Report of your Board, the report of the progress made in adding three stories to the Engineering Societies Building on West Thirty-ninth Street was brought up to date, and the statement was made that the Fifty-seventh Street property of the Society had been placed on the market. The Report of the Secretary of the Society,* who was also a member of the Building Committee of the United Engineering Society, gives in detail the cost of the work and a general description of the quarters now occupied by the Society, together with a financial statement of the cost, which need not be repeated here.

The Headquarters of the Society were moved to the Engineering Societies Building during October. It was necessary, however, that the stock of Society publications be left in the Fifty-seventh Street House, because the new stack room in Thirty-ninth Street is not yet ready for the books. It is expected that very soon the stacks will be completed, and the library books now shelved temporarily on the twelfth floor will be moved to their permanent place, giving shelf room for necessary storage of the Society's publications, and that in the near future all the Society's property will be moved to the new quarters.

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* *Proceedings*, Vol. XLIII, p. 667 (November, 1917).

The condition of the real-estate market, due to the war, has made it impossible to dispose of the property of the Society without great financial sacrifice, and it remained unoccupied for about two months.

The United States Food Administration, of which Herbert C. Hoover, M. Am. Soc. C. E., is the head, was seeking a suitable place for carrying on its work, and that of the New York Federal Food Board, and the House of the Society, being admirably suitable in every way, was offered by your Board, and accepted by the National Food Administration. Under the terms of the agreement the Food Administration assumes the entire cost of the maintenance of the building during the term of its occupancy, and agrees to vacate on short notice should the Society find it necessary to give such notice. The home of the Society for the past twenty years, therefore, continues, after a brief interval, to fulfill a useful public purpose.

WAR ACTIVITIES

At the time of the Annual Meeting, January 18th, 1917, an address was made by John Howard Whitehouse, Esq., Member of Parliament, on the Changes in Economic and Social Conditions in England due to the War.

Under date of February 6th, 1917, President Pegram signed a joint telegram, with the Presidents of the other Founder Societies, addressed to the President of the United States, expressing the cordial unity of the 30 000 Engineers representing the membership of these four Societies in the support of Congress and the Administration in its stand for freedom and safety on the seas, and their assistance in the organization of Engineers for the service of our country in case of war.

At the meeting of March 7th, 1917, resolutions were unanimously adopted expressing cordial approval and commendation of the severing of diplomatic relations with Germany, and, as loyal citizens, tendering to the Government all the service of which we severally and collectively are capable, and urging Congress to exercise its Constitutional power "to raise and support armies" by the immediate establishment of a permanent and democratic system of defence based on universal service and training under direct and exclusive Federal control. A copy of these resolutions was transmitted immediately to the President of the United States, to the Secretary of War, and other members of the Cabinet, and to the members of both Congressional Committees on Military Affairs.

On March 14th, 1917, J. deB. W. Gardiner, Assoc. M. Am. Soc. C. E. (formerly an officer of the U. S. Army), addressed the meeting on "The Present Situation of the Great War", giving an exposition of the strategy and tactics which led up to the present conditions, and, based on the events of the past two years, a discussion of the logical outcome; and on April 4th, 1917, Mr. John R. MacArthur, a member of the American Industrial Commission which visited France in 1916, addressed the Society on "France at Work and at War, as seen on a Recent Visit".

On April 18th, 1917, your Board adopted the following resolutions:

"*Whereas,* a state of war, between our Country and a great foreign power, now exists, and

"*Whereas,* all previous experience of our own, no less than that of other nations, has demonstrated the danger, as well as insufficiency, of relying on volunteer armies and navies for the national defense; be it

"*Resolved:* That Congress be petitioned to pass at once a bill providing for universal military training and service, which we hold to be the only proper, democratic, and efficient way for creating the public defense; and

"*Be it further resolved:* That a copy of these resolutions be transmitted to the President of the United States and to each Senator and Member of the House of Representatives."

In the *Proceedings* for May, 1917, a letter from the Hon. William C. Redfield, Secretary, Department of Commerce, referring to the necessity for increased production of food, and urging co-operation with the Department of Agriculture in its campaign to increase the crops of the country, was published for the information of the membership.

Under date of July 31st, 1917, a cablegram was received from John F. Stevens, M. Am. Soc. C. E., sending, in behalf of the Central Board of Engineers of Ways and Communications, fraternal greetings, and requesting the Society to thank the United States for sending the Advisory Commission to Russia. President Pegram transmitted this to the President of the United States, and received a cordial reply.

The Society has, so far as it could, aided, through its membership, in the taking of the military census and inventory, and in the recruiting of Engineer Regiments. Letters have been received from the Director of the Military Census of New York City, and from the Mayor, expressing great appreciation of this work.

The "Roll of Honor" published in the *Proceedings* for November, 1917, contained 575 names. A month later, the list published in the December *Proceedings* contained the names of 743 officers, and at the present date our records show that there are 929 members of the Society in uniform, almost all of them being commissioned officers.

A report has been received from Messrs. Alfred Craven and A. M. Hunt, the representatives of this Society on the Naval Consulting Board, giving a brief summary of its work. The report calls attention to the fact that in addition to the two direct representatives of the Society on the Board, four other of its members are also members of the Society. This report will be published in the *Proceedings* for January, 1918.

GENERAL

The attention of members is called to a number of interesting matters which have been published in *Proceedings* during the year, as follows:

Correspondence with regard to the question of contingent fees,* which was ordered printed for the information of members.

Resolutions adopted by the San Diego Association of Members with regard to a proposed Bill for the Licensing of Architects.†

A Bill for the Licensing of Engineers, which was adopted by the Legislature of the State of Florida, May 18th, 1917, and became a law. This Bill, the full text of which was published,‡ was largely based on the draft of a Bill prepared by a Joint Committee of the Founder Societies, but which was never adopted by this Society, and it is believed is the first legislation of the kind adopted in any State.

Resolutions were adopted by your Board looking to a closer relation between this Society and the Canadian Society of Civil Engineers at its meeting of October 9th, 1917.§ These resolutions were forwarded to the Canadian Society of Civil Engineers, and resolutions cordially reciprocating the co-operative spirit expressed have been received from that Society.

In October, 1917, the Board appropriated and paid the sum of $500 toward the erection of a Memorial to the late John Ericsson, Honorary Member, which is to be placed in Washington, D. C.

On November 1st, 1917, the Executive Committee of the Board adopted a resolution‖ condemning the eight per centum super tax on net incomes of more than $6 000 of individuals, and requesting its repeal, characterizing it as discriminatory and unjust. These resolutions were forwarded to the Chairman of the Finance Committee of the Senate and of the Ways and Means Committee of the House, and each member of the Society was urged to act individually in communicating directly with his representatives in Congress along the same lines.

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* *Proceedings*, Vol. XLIII, pp. 332 and 405 (May and August, 1917).
† " " " p. 341 (May, 1917).
‡ " " " " 408 (August, 1917).
§ " " " " 642 (November, 1917).
‖ " " " " 672 (November, 1917).

Resolutions* were adopted by the Executive Committee, on November 27th, 1917, calling attention to the fact that the supply of technically trained Engineers for present and future usefulness should be continuous, and asking that all possible consideration be given to students, who are certified by Engineering Schools of recognized reputation as having shown their capacity to become Engineers, to continue their education to graduation, if possible, and in any event, until necessity demands their call to active service. These resolutions were forwarded to the Secretary of War, and to other public officials, as well as to the other Founder Societies and the Engineering Council. Action has been taken on this matter by the War Department, as is shown by the letter of Gen. William M. Black, M. Am. Soc. C. E., Chief of Engineers, U. S. A.†

On March 3d, 1917, Director Otis F. Clapp died, and Frederic H. Fay was appointed by the Board to fill his unexpired term.

On June 26th, 1917, Director F. G. Jonah resigned as a member of the Board of Direction, owing to the fact that he was in active service in France. The resignation was accepted with regret by the Board, and John W. Alvord was appointed to fill the vacancy for the unexpired term.

A Committee, appointed by the Board on July 9th, 1916, to consider and report on the desirability of the establishment of some form of an Employment Bureau in connection with the activities of the Society, reported in April, 1917. The Report‡ of this Committee, in accordance with one of its recommendations, was referred by your Board to Engineering Council.

The Report of a Committee, appointed by your Board, on the Relations of Local Associations of the American Society of Civil Engineers to that Society, to other Engineering Organizations and Engineers, and to the Public, was presented to the April 17th, 1917, Board meeting, and its recommendations were adopted and ordered printed in *Proceedings*.§ The attention of all Local Associations was especially called to this report, and several of them considered the matter. The resulting discussions so far as received have been published.‖

During the year the constitution of three new Associations (Duluth, Nebraska and Pittsburgh) have been approved by the Board, thus increasing the number of Local Associations to twenty-two. All statistics, minutes of meetings, and items of interest forwarded to the Secretary have been published in *Proceedings*.

During the year the Report of a Committee of the Board on a proposed Revision of the Constitution was received. The results of the work of this Committee have been presented to the membership, under Article IX of the Constitution, in a circular prepared by the Publication Committee.

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* *Proceedings*, Vol. XLIII, p. 759 (December, 1917).

† " " " " 760 (" ").

‡ " " " " 330 (May, 1917).

§ " " " " 327 (" ").

‖ " " " " 584 (October, 1917).

The attention of members is called to the interesting Progress Report of the Alfred Noble Memorial Committee;* also to the article on the activities of the Society during the past twenty-five years prepared by Dr. Hunt, which describes quite fully the Society's old and new Headquarters, Library and Publications, as well as other matters of historic and present interest.†

The Society has been represented on the Engineering Foundation Board by Messrs. J. Waldo Smith and Chas. Warren Hunt. The report of the Secretary of the Foundation for the year ending September, 1917, has been published.‡

During the year the Engineering Council has been formed. Each of the four Founder Societies has four representatives on this body, and four representatives chosen by the United Engineering Society. The rules under which this new body is to operate will be found in *Proceedings.*§

The principal function of the Council is stated in the By-Laws of the U. E. S., as follows:

> "The Council may speak authoritatively for all member societies on all public questions of a common interest or concern to engineers, unless objection be made by a majority of the representatives present of one of the Founder Societies or by one-fourth of the representatives present and voting. It shall defer any action which is opposed as aforesaid; such suspended action shall be referred to the governing bodies of the societies whose representatives have protested, for an expression of opinion of a veto upon further action, and may then be reconsidered if such societies have agreed."

It has been found expedient to secure an Executive to manage the many activities of the United Engineering Society, (which is the business and financial custodian of the Founder Societies and of other related funds) the Engineering Foundation, and the Engineering Council, and Alfred D. Flinn, Director of this Society, has been selected by the Boards representing these three organizations, jointly as their Secretary. Mr. Flinn assumed office on January 1st, 1918.

FINANCES

At the time of the last report of the Board, $54 000 had been paid to the United Engineering Society on account of building expenses, and during 1917 additional payments aggregating $208 500 have been made, bringing the total cost of the share of this Society on this account up to $262 500. In order to secure this money, a mortgage debt of only $150 000 has been incurred, the balance, $112 500, having been paid out of reserve and current funds.

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* *Proceedings*, Vol. XLIII, p. 648 (November, 1917).

† " " " " 2251, Papers and Discussions (December, 1917).

‡ " " " " 673 (November, 1917).

§ " " " " 342 (May, 1917).

Other references in this report cover details incident to the change of Society Headquarters; and the details of all receipts and expenditures are fully set forth in the reports of the Secretary and Treasurer appended hereto.

By order of the Board of Direction.

CHAS. WARREN HUNT,
Secretary.

REPORT OF THE SECRETARY FOR THE

To the Board of Direction of the

Gentlemen:—I have the honor to present a statement of Receipts and Disbursements for the fiscal year of this Society, ending December 31st, 1917. I also append a general Balance Sheet showing the condition of the affairs of the Society.

Respectfully submitted,

Chas. Warren Hunt,
Secretary.

Receipts.

Balance on hand December 31st, 1916, in Bank and in hands of Secretary		$49 888.28
Entrance Fees	$16 195.00	
Current Dues	93 626.88	
Past Dues	6 312.83	
Advance Dues	30 426.26	
Certificates of Membership	806.25	
Badges	3 591.17	
Sales of Publications	3 879.43	
Library	167.77	
Annual Meeting	1 041.05	
Binding	4 921.34	
Interest	5 904.82	
Compounding Dues	575.00	
Miscellaneous	350.24	
Mortgage	130 000.00	
Old Paper and Books Sold	185.00	
500 Collapsible Chairs, sold to U. E. S.	564.30	
		$298 547.34
		$348 435.62

YEAR ENDING DECEMBER 31st, 1917.

American Society of Civil Engineers.

Disbursements.

Salaries of Officers	$15 100.00	
Mileage of Directors	4 492.22	
Mileage of Nominating Committee	565.30	
Work of Committees (Including Mileage, $328.26)	4 894.46	
Clerical Help	21 313.90	
Caretaking	1 916.64	
Publications	33 696.97	
Postage	8 259.77	
General Printing	4 000.39	
Office Supplies	1 178.36	
House Supplies	146.66	
Reading Room Maintenance	182.04	
Badges	2 343.60	
Certificates of Membership	691.00	
Binding	63.15	
Prizes	265.39	
Annual Meeting	2 305.51	
Annual Convention	217.75	
Maintenance of House	25.82	
Heat, Light and Water	1 131.71	
Furniture	7 932.62	
Interest on Mortgage	1 459.73	
Insurance	161.25	
Current Business (Includes Telephone Service and all Expenses of Meetings)	4 831.07	
Petty Expenses	126.74	
U. E. S. Assessment for New Quarters (two months)	1 797.44	
U. E. S. Library Assessment (one year)	4 000.00	
U. E. S. Building Enlargement	208 500.00	
U. E. S. Special Assessment, Alteration of Building	1 632.36	
U. E. S. Final Settlement on Account of Searches	228.85	
New Society Headquarters (Paneling)	5 100.00	
Moving Expenses	155.50	
Alfred Noble Memorial Fund	1 221.45	
Miscellaneous	153.34	
		$340 090.99
Balance on hand, December 31st, 1917:		
In Garfield National Bank	$6 844.63	
In Hands of Secretary	1 500.00	
		8 344.63
		$348 435.62

GENERAL BALANCE SHEET, DECEMBER 31st, 1917.

Accompanying Report of the Secretary.

Assets.		
Three Lots (Actual cost $185 406.20) Estimated Value		$350 000.00
Building (Cost, less 2% annually for depreciation)		125 510.48
New Society Headquarters		5 100.00
Furniture		16 895.71
Publications on hand, (inventoried cost)		23 938.14
New York City non-taxable 4¼% bonds.		10 300.00
Interest accrued on Investments		141.67
Library: Cash expended for books, etc.	$22 122.22	
Donations (estimated)	72 310.83	94 433.05
United Engineering Society, Treasurers Receipts for cash payments, a/c enlargement of Building		262 500.00
Due from Members		15 268.01
Due from Non-Members		847.95
Unexpired Fire Insurance (Premium)		251.76
Alfred Noble Memorial (Loan)		1 200.00
Cash		8 344.63
		$914 731.40

Liabilities.	
Dues for 1918 paid in Advance	$30 426.26
Mortgage Debt	150 000.00
Interest accrued on Mortgage	2 404.17
Funds invested in Society House, Lots and Library*	28 590.78
Herbert Steward Library Fund	2 060.00
Joseph G. Swift Library Fund	1 030.00
Balance of Donations on account of Work of Special Committees	2 641.84
Surplus (including Reserve Fund of $7 210.00)	697 578.35
	$914 731.40

We have audited the accounts of the American Society of Civil Engineers for the year ended December 31st, 1917, and (assuming that the estimate of the property valuation is correct) we certify that in our opinion the above Balance Sheet shows correctly the financial condition of the Society as of that date.

New York,
January 8th, 1918.

Lybrand, Ross Bros. & Montgomery,
Certified Public Accountants.

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* Compounding Dues Fund, $12 330.00; Norman Medal Fund, $1 000.00; Rowland Prize Fund, $1 222.50; Collingwood Prize Fund, $1 000.00; Fellowship Fund, $13 038.28.

REPORT OF THE TREASURER OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS FOR THE YEAR ENDING DECEMBER 31st, 1917.

In compliance with the provisions of the Constitution, I have the honor to present the following report for the year ending December 31st, 1917:

Balance on hand, December 31st, 1916			$49 888.28
Receipts from current sources, January 1st to December 31st, 1917		$163 655.67	
Interest from U. E. S. on building funds advanced		4 891.67	
June 14th, 1917, second installment on mortgage loan	$30 000.00		
July 14th, 1917, third installment on mortgage loan	40 000.00		
Aug. 31st, 1917, fourth installment on mortgage loan	45 000.00		
Oct. 31st, 1917, fifth installment on mortgage loan	15 000.00	130 000.00	298 547.34
Payment of audited vouchers for current business, January 1st to December 31st, 1917		$115 726.01	
Payments on account of Engineering Societies Building enlargement		208 500.00	
Special assessment for alteration of Fifth floor of Engineering Societies Building		1 632.36	
Alfred Noble Memorial (Loan to Committee)		1 200.00	
New Society Headquarters:			
Expenses due to extra paneling.	$5 100.00		
Furniture (new and refinishing old)	7 932.62	13 032.62	
Balance on hand, December 31st, 1917:			
In Garfield National Bank	$6 844.63		
In hands of Secretary	1 500.00	8 344.63	
		$348 435.62	$348 435.62

Respectfully submitted,

Geo. W. Tillson,
Treasurer.

New York, January 8th, 1918.

ACCESSIONS TO THE UNITED ENGINEERING SOCIETY LIBRARY

(From December 1st to 31st, 1917)

DONATIONS*

The statements made in these notices are taken directly from the books themselves, and this Society is not responsible for them.

STANDARD WIRING FOR ELECTRIC LIGHT AND POWER;

As Adopted by the Fire Underwriters of the United States, in Accordance with the National Electrical Code, with Explanations, Illustrations, and Tables Necessary for Outside and Inside Wiring and Construction for All Systems, Together with a Section on House Wiring. By H. C. Cushing, Jr. 23d ed. N. Y., The Author, 1917. 360 pp., 47 illus., 7 x 4 in., leather.

The object of the book has been to standardize this work. The author has had the co-operation of the Electrical Committee of the National Fire Protection Association, the Wiring Committee of the Commercial Section of the National Electric Light Association, and the Society for Electrical Development.

RADIO COMMUNICATION:

Theory and Methods, with an Appendix on Transmission over Wires. By John Mills. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 205 pp., 126 illus., 7 x 5 in., leather.

The substance of a course of lectures given to a company of the U. S. Reserve Signal Corps troops, the members of which had had some previous training in electrical engineering. The aim has been to present the fundamental principles and methods without using any mathematics except elementary algebra or presupposing more than a limited knowledge of physics.

THE ELECTRIC VEHICLE HAND-BOOK.

By H. C. Cushing, Jr., and Frank W. Smith. 5th ed. N. Y., H. C. Cushing, Jr. (copyright 1917). 388 pp., 172 illus., 7 x 4 in., flexible cloth. $2.00.

The object of this handbook is to set forth as clearly as possible the fundamental principles in the operation, care, and maintenance of electric vehicles, their batteries, tires, motors, controllers, and accessories.

PROPERTIES OF STEAM AND AMMONIA.

By G. A. Goodenough. 2d ed. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 126 pp., 7 illus., 3 pl., 10 x 7 in., cloth. $1.25.

Tables of the properties of saturated steam and ammonia, based on new formulations which give more accurate data than those previously used to calculate such tables. Various supplementary tables are included.

NON-TECHNICAL CHATS ON IRON AND STEEL

And Their Application to Modern Industry. By LaVerne W. Spring. N. Y., Frederick A. Stokes Company (copyright 1917). 11 + 358 pp., 294 illus., 8 x 6 in., cloth. $2.50.

An account of the metallurgy and mechanical working of iron and steel, based on the author's practical experience as a chemist and metallurgist in the industry. Written in popular style and very fully illustrated. Intended to provide a readable general review of modern methods for those unacquainted with the subject. Includes a list of references to other books.

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* Unless otherwise specified, books in this list have been donated by the publishers.

A PRACTICE BOOK IN ELEMENTARY METALLURGY.

By Ernest Edgar Thum. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 8 + 313 pp., 59 illus., 9 x 6 in., cloth. $2.75.

Represents the laboratory course in metallurgy given to co-operative students in mechanical, civil, and electrical engineering at the University of Cincinnati. The intention has been to provide a set of detailed directions for experimental procedure in studying the metallic materials of engineering construction, which would enable large numbers of students to be taught with a minimum of equipment and personal supervision.

FLOTATION.

By T. A. Rickard and O. C. Ralston. San Francisco, Mining and Scientific Press, 1917. 416 pp., 131 illus., 9 x 6 in., cloth. $3.00.

This book is a compilation of articles by a number of authors, many of which have appeared in mining periodicals. These articles have been arranged and connected to form a report on recent progress in the application of the process, giving the latest available information on its technology. It discusses the history, principles, and theory of flotation, costs, methods, troubles, etc., and includes a review of the litigation which has arisen.

UNITED STATES RIFLES AND MACHINE GUNS:

A Detailed Account of the Methods Used in Manufacturing the Springfield, 1903, Model Service Rifle; also Descriptions of the Modified Enfield Rifle and Three Types of Machine Guns. By Fred H. Colvin and Ethan Viall. N. Y., McGraw-Hill Book Company, Inc.; Lond., Hill Publishing Co., Ltd., 1917. 332 pp., 2347 illus., 12 x 9 in., cloth. $3.00.

Prepared at the request of the Ordnance Bureau, United States Army, to assist manufacturers in undertaking contracts. Shows the methods in use at the Springfield Armory during the fall of 1916. The machine guns included are the Lewis, the Maxim, the Vickers, and the United States Machine Rifle.

THE EXPORTERS' DIRECTORY OF JAPAN, 1917.

Tokyo, Imperial Commercial Museum of the Department of State for Agriculture and Commerce. 415 + 26 pp., 9 x 6 in., flexible cloth. $2.50.

A directory of Japanese merchants and manufacturers engaged in the export business, arranged under the lines of merchandise in which they deal. A brief description of Japan, giving considerable general information, is included.

THOMAS' REGISTER OF AMERICAN MANUFACTURERS, 1917.

The Largest Classified Reference Book in the World, the Only One in the United States Covering All Lines. 9th ed. N. Y., Thomas Publishing Company, 1917. 3900 pp., 12 x 10 in., cloth. $15.00.

Includes lists of manufacturers classified alphabetically and according to business, trade papers classified by trades, banks, boards of trade, chambers of commerce, etc., and of manufacturers' representatives. This edition, according to the publisher, contains 400 pages more than the previous one.

PRACTICAL PYROMETRY;

The Theory, Calibration, and Use of Instruments for the Measurement of High Temperatures. By Ervin S. Ferry, Glenn A. Shook, Jacob R. Collins. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 147 pp., 73 illus., 8 x 6 in., cloth. $1.50.

Intended for use by college students, technically trained observers who deal with processes requiring high temperature measurements, and less trained observers who may make the measurements. Includes a discussion of the theoretical principles involved and a description of the manipulative details. Experiments for purposes of instruction are also given. Contents: Standard Temperature Scales; Resistance Pyrometry; Thermoelectric Pyrometry; Radiation Pyrometry; Optical Pyrometry; Conclusion; Tables.

A HANDBOOK FOR CANE-SUGAR MANUFACTURERS AND THEIR CHEMISTS.

By Guilford L. Spencer. 6th ed., enl. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 15 + 561 pp., 97 illus., 7 x 4 in., leather. $3.50.

Contains a review of the processes of cane-sugar manufacture, practical instruction in sugar-house control, selected methods of analysis, etc. Various typographical errors of earlier editions have been corrected, and a chapter on Evaporation and Juice Heating has been added.

AN INTRODUCTION TO THEORETICAL AND APPLIED COLLOID CHEMISTRY;

The World of Neglected Dimensions. By Dr. Wolfgang Ostwald. Authorized Translation from the German by Dr. Martin H. Fischer. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 15 + 232 pp., 45 illus., 1 por., 9 x 6 in., cloth. $2.50.

The author has selected from his lectures before American and Canadian universities during 1913 and 1914 the five which he considers best adapted to give a general survey of modern colloid chemistry, as a pure and as an applied science, in a form readily intelligible to the general reader.

THE CHEMISTRY OF COLLOIDS:

Part I, Kolloidchemie, by Richard Zsigmondy; Translated by Ellwood B. Spear. Part II, Industrial Colloidal Chemistry, by Ellwood B. Spear. A Chapter on Colloidal Chemistry and Sanitation, by John Foote Norton. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 288 pp., 38 illus., 9 x 6 in., cloth. $3.00.

Professor Spear has supplemented his translation of Zsigmondy's "Kolloidchemie" by adding several brief chapters on certain matters which are of particular interest to the technical chemist. The book is supplied throughout with numerous references to the literature on colloids. Contents: General Considerations; Classification; Properties of Colloids; Theory; Inorganic Colloids; Colloidal Non-metals; Colloidal Oxides; Colloidal Sulfides; Colloidal Salts; Organic Colloids; Dyestuffs; Protein Bodies; Introduction to Part II; Smoke; Flue Fumes; Liquid Particles in Gases; Rubber; Tanning; Milk; Colloidal Graphite; Clays; Colloids in Sanitation.

GRAPHICS.

By H. W. Spangler. N. Y., John Wiley & Son, Inc.; Lond., Chapman & Hall, Ltd., 1917. 95 pp., 88 illus., 9 x 6 in., cloth. $1.25.

This work contains the substance of a series of lectures given to students at the University of Pennsylvania, covering the fundamental principles of graphics.

GREENHOUSES;

Their Construction and Equipment. By W. J. Wright. N. Y., Orange Judd Company; Lond., Kegan Paul, Trench, Trübner & Co., Ltd., 1917. 16 + 269 pp., 131 illus., 8 x 5 in., cloth. $1.60.

Intended for gardeners rather than for manufacturers of greenhouses. It gives, however, considerable attention to the question of their design, construction, and erection, which will be useful to engineers engaged in building such structures. Costs are given.

TABLES OF VELOCITY OF WATER IN OPEN CHANNELS.

Derived from Kutter's Formula. By Arthur Alvord Stiles. (*Bulletin No. 6* of the State Reclamation Department of Texas, August, 1917.) Austin, State Reclamation Department, 1917. 130 pp., 9 x 6 in., leather.

These tables give the velocity, in feet per second, for slopes of the water surface, expressed in the ratio of the vertical to the horizontal, varying from 0.00055 to 0.010, and for twenty-five coefficients of roughness varying from 0.006 to 0.080.

RECLAIMING THE ARID WEST:

The Story of the United States Reclamation Service. By George Wharton James. N. Y., Dodd, Mead and Company, 1917. 22 + 411 pp., 67 illus., 9 x 6 in., cloth. $3.50.

A popular illustrated account of the various irrigation projects undertaken by the United States Reclamation Service. The history of each project is given, together with an outline of its engineering features.

TABLES OF CUBIC CONTENTS OF LEVEE EMBANKMENTS.

Designed by Arthur Alvord Stiles. (*Bulletin No. 5* of the State Reclamation Department of Texas, June, 1917.) Austin, State Reclamation Department, 1917. 212 pp., 1 pl., 9 x 6 in., leather.

Contents: Cubic Contents of Levee Embankments; Cubic Contents of Component Parts of Levee Embankments; Cubic Contents, Dimensions and Component Parts of Road Approaches to Levee Embankments.

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(From December 7th, 1917, to January 3d, 1918)

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MEMBERS

		Date of Membership.
Aikenhead, James Ray. Engr.-in-Chg., New York Office, Henry R. Kent & Co., 141 Broadway, New York City	Assoc. M. M.	Feb. 7, 1906 Nov. 27, 1917
Bassel, Guy Mannering. Constr. Engr., Aluminum Co. of America, Maryville, Tenn.	Assoc. M. M.	Feb. 6, 1907 Nov. 27, 1917
Cole, Clinton Llewellyn. Cons. Engr., 36 Pearl St., Hartford (Res., 309 Broad St., Meriden), Conn	Assoc. M. M.	May 6, 1908 Nov. 27, 1917
Davis, Wilbur Ward. With Boston Transit Comm., 53 Ferdinand St., Melrose Highlands, Mass		Nov. 27, 1917
Du Moulin, Walter Louis. Mech. Engr., Andes Copper Min. Co., Casilla 230, Antofagasta, Chile	Jun. Assoc. M. M.	Feb. 1, 1910 Dec. 3, 1913 Oct. 9, 1917
Estes, Franklin Edward. Capt., 17th Ry. Engrs., Am. Exp. Forces, France, Care, Adjt. Gen., Washington, D. C	Assoc. M. M.	Feb. 7, 1906 June 12, 1917
Feild, Julian Clarence. Cons. Engr., 105 Feild Bldg., Denison, Tex	Assoc. M. M.	Jan. 17, 1916 Nov. 27, 1917
Garlow, Ezra Clark. Chf. Engr., Alliance Structural Co., 1818 South Cherry Ave., Alliance, Ohio		Nov. 27, 1917
Goldsmith, William. Constr. Engr., New York City Dept. of Correction, New Hampton, N. Y	Assoc. M. M.	Mar. 4, 1913 Nov. 27, 1917
Wright, Jesse Clark. Engr., W. M. Ledbetter & Co., 651 Pacific Elec. Bldg., Los Angeles, Cal	Assoc. M. M.	Mar. 14, 1916 Nov. 27, 1917

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Andrus, Vincent Richardson. Chf. Engr., J. Goldberg & Son, 334 Lathrope Bldg., Kansas City, Mo		Nov. 27, 1917
Barker, Richard McLean. Chf. Engr., Lawrence County Road Comm., Lawrenceburg, Tenn		Nov. 27, 1917
Bates, Francis. Div. Engr., M. of W., Los Angeles & Salt Lake R. R., 1332 Fourth Ave., Los Angeles, Cal.		Nov. 27, 1917

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Bowe, Thomas Francis. Association Bldg., Rutherford, N. J....	Nov. 27, 1917
Bulkeley, Oscar Ernest. Supt., Water Dept., Jackson, Mich....	Oct. 9, 1917
Bush, Lee Marshall. Junior Engr., Interstate Commerce Comm., Burlingame, Kans....	Nov. 27, 1917
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Edwards, Latta Vanderion. Prof. of Ry. and Highway Eng., State Coll. of Washington, Pullman, Wash....	Sept. 11, 1917
Ellis, John Russell. Asst. State Highway Engr., R. F. D. No. 4, Jefferson City, Mo....	Nov. 27, 1917
Findley, Raymond Hanson. Supt. of Track and Roadway, Omaha & Council Bluffs St. Ry., 2501 Kansas Ave., Omaha, Nebr....	Nov. 27, 1917
Franks, John Brandon. 1st Sergeant, Co. C, 353d Inf., N. A., Camp Funston, Kans....	Nov. 27, 1917
Friel, Grant. Supt. of Maintenance, Los Angeles County Road Dept., Los Angeles, Cal....	Nov. 27, 1917
Hendrie, Matthew Charles. 2557 Ash St., Denver, Colo..	Nov. 27, 1917
Holmes, Hugh Browning. 66 Broadway, New York City..	Nov. 27, 1917
Humphrey, Thomas Paul. Designer, Bridge Dept., Kansas City Terminal Ry., 20 East 53d St., Kansas City, Mo.	Nov. 27, 1917
Hunt, James O'Connor. Asst. Engr., So. Ry., 411 Henson Bldg., Knoxville, Tenn....	Nov. 27, 1917

ASSOCIATE MEMBERS (*Continued*)

		Date of Membership.
Jebejian, Nejib Hovhanness. 5903 Walnut St., Philadelphia, Pa.		Nov. 27, 1917
Juengst, William George. 513 Missouri Ave., East St. Louis, Ill.		Nov. 27, 1917
Knapp, Frank Hiram. 225 Park St., Bridgeport, Conn.		Oct. 9, 1917
Love, William Lewis. Chf. Engr., Howe & Wise, 629 Chronicle Bldg., Houston, Tex.		Nov. 27, 1917
Macqueen, Philip Outerbridge. Acting Gen. Foreman, Municipal Eng. Div., Panama Canal, P. O. Box 522, Cristobal, Canal Zone, Panama		Nov. 27, 1917
May, Charles Culbertson. 5501 Twenty-first Ave., N. E., Seattle, Wash.		Sept. 11, 1917
Miller, Robert Patchen. Chf. Engr., Union Iron Works of Los Angeles, Inc., 519 Stimson Bldg., Los Angeles, Cal.		Nov. 27, 1917
Norris, Claire Green. Res. Engr., A. T. & S. F. R. R., Caney, Kans.		Nov. 27, 1917
Norris, Robert. Superv. Engr. for Gardner S. Williams, Cornwell Bldg., Ann Arbor, Mich.		Nov. 27, 1917
Quarles, Ben Tarver. State House Hotel, Waco, Tex.		Nov. 27, 1917
Reding, James Handyside. Capt., Co. A, 112th Engrs., Camp Sheridan, Ala.		Oct. 9, 1917
Rice, John Turner. Capt., Engr. R. C. (*Unassigned*), Box 452, Imperial, Cal.		Nov. 27, 1917
Rice, Roger Cushing. Dist. Engr., U. S. Geological Survey, Water Resources Branch, 25 Federal Bldg., Topeka, Kans.	Jun.	Jan. 2, 1912
	Assoc. M.	Oct. 9, 1917
Roberts, Leo Bond. Lieut., Engr. R. C., 25th Engrs., Camp Devens, Mass.		Nov. 27, 1917
Staehle, Gilbert Cobb. Engr., Trussed Concrete Steel Co., 603 Metropolitan Bank Bldg., Minneapolis, Minn.	Jun.	Dec. 3, 1913
	Assoc. M.	Nov. 27, 1917
Straney, John William. Field Engr. on Constr., Braden Copper Co., Rancagua, Chile		Sept. 11, 1917
Swartz, Leon. Master Engr., 15th Engrs., Am. Exp. Force, France	Jun.	April 1, 1914
	Assoc. M.	Oct. 9, 1917
Tamm, Alfred. Chf. Engr., United Irrig. Co., Mission, Tex.		Nov. 27, 1917
Waite, Earle Chester. Civ. Engr., Bethlehem Steel Co. (Res., University Heights), South Bethlehem, Pa.	Jun.	Mar. 14, 1916
	Assoc. M.	Nov. 27, 1917
Wilson, Louis Arthur. Sibley, Iowa		Nov. 27, 1917

JUNIORS

Duncan, Malcolm. Instr., Civ. Eng. Dept., Univ. of Pennsylvania, Philadelphia, Pa.	Nov. 27, 1917

JUNIORS (*Continued*)	Date of Membership.
McIntyre, William John. Draftsman, T. A. Edison, Inc., 17 Lakeside Pl., Morristown, N. J	Nov. 27, 1917
Robertson, Fonzie Eugene. Lieut., F. A. R. C., Marlin, Tex.	June 11, 1917
Weekes, Clifton L'Orignal. Care, Jenks B. Jenkins, Valuation Dept., B. & O. R. R., Baltimore, Md	Oct. 9, 1917
Williamson, Lee Hoomes. Care, Braden Copper Co., Constr. Dept., Rancagua, Chile	Oct. 9, 1917

REINSTATEMENTS

ASSOCIATES	Date of Membership.
McIntire, Thomas Burton	Oct. 9, 1917

RESIGNATIONS

MEMBERS	Date of Resignation
Boright, William Parsons	Dec. 31, 1917
Fitch, Graham Denby	Dec. 31, 1917
Garrison, Frank Lynwood	Dec. 31, 1917
Smith, George Pliny	Dec. 31, 1917
Watt, David Alexander	Dec. 31, 1917
Wilson, Herbert Michael	Dec. 31, 1917

ASSOCIATE MEMBERS	
Barnes, Walter Esmond	Dec. 31, 1917
Baxter, David Elder	Dec. 31, 1917
Du Bois, Julian	Dec. 31, 1917
Esten, Howard Foss	Dec. 31, 1917
Fraser, Guy Owen	Dec. 31, 1917
Fuller, Andrew Daniel	Dec. 31, 1917
Gehring, Herbert August	Dec. 31, 1917
Gilbert, George Herbert	Dec. 31, 1917
Hutchins, Ralph	Dec. 31, 1917
Langley, John Edward	Dec. 31, 1917
Malcomson, Alfred Sidney	Dec. 31, 1917
Meem, James Lawrence	Dec. 31, 1917
Pfeiffer, George Whitfield	Dec. 31, 1917
Ranson, Birtram Willard	Dec. 31, 1917
Shank, Lyman Chambers	Dec. 31, 1917
Sherman, Henry Andrew	Dec. 31, 1917
Turner, Douglas Barlow	Dec. 31, 1917
Underhill, Grandison Gridley	Dec. 31, 1917
Vickers, Thomas McElderry	Dec. 31, 1917

ASSOCIATE MEMBERS (*Continued*)	Date of Resignation
Weigman, William Julius	Dec. 31, 1917
Werbin, Israel Vernon	Dec. 31, 1917
Wills, Arthur John	Dec. 31, 1917
ASSOCIATES	
Cushman, Allerton Seward	Dec. 31, 1917
Phillips, Henry Ayling	Dec. 31, 1917
JUNIORS	
Pickus, Joseph	Dec. 31, 1917
Pitman, Laurence Minot	Dec. 31, 1917
See, Russell Alva	Dec. 31, 1917

DEATHS

Brown, John Griffiths. Elected Associate, July 9th, 1906; Member, September 3d, 1913; died October 22d, 1917.

Herrick, Henry Augustus. Elected Member, May 7th, 1890; died December 14th, 1917.

Hobson, Joseph. Elected Member, February 5th, 1890; died December 19th, 1917.

Welton, Nelson James. Elected Fellow, January 20th, 1873; died June 5th, 1917.

Total Membership of the Society, January 3d, 1918, 8 593.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(September 16th to 30th, 1917)

NOTE.—*This list is published for the purpose of placing before the members of this Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(2) *Proceedings,* Engrs. Club of Phila., Philadelphia, Pa.
(3) *Journal,* Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal,* Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Transactions,* Can. Soc. C. E., Montreal, Que., Canada.
(6) *Journal,* Am. Inst. Architects, Washington, D. C., 50c.
(7) *Gesundheits Ingenieur,* München, Germany.
(8) *Stevens Indicator,* Hoboken, N. J., 50c.
(9) *Industrial Management,* New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, 432 Fourth Ave., New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News-Record,* New York City, 15c.
(15) *Railway Age Gazette,* New York City, 15c.
(16) *Engineering and Mining Journal,* New York City, 15c.
(17) *Electric Railway Journal,* New York City, 10c.
(18) *Railway Review,* Chicago, Ill., 15c.
(19) *Scientific American Supplement,* New York City, 10c.
(20) *Iron Age,* New York City, 20c.
(21) *Railway Engineer,* London, England, 1s. 2d.
(22) *Iron and Coal Trades Review,* London, England, 6d.
(23) *Railway Gazette,* London, England, 6d.
(24) *American Gas Engineering Journal,* New York City, 10c.
(25) *Railway Mechanical Engineer,* New York City, 20c.
(26) *Electrical Review,* London, England, 4d.
(27) *Electrical World,* New York City, 10c.
(28) *Journal,* New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal,* Royal Society of Arts, London, England, 6d.
(30) *Annales des Travaux Publics de Belgique,* Brussels, Belgium, 4 fr.
(31) *Annales* de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand, Brussels, Belgium, 4 fr.
(32) *Mémoires et Compte Rendu des Travaux,* Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil,* Paris, France, 1 fr.
(34) *Portefeuille Economiques des Machines,* Paris, France.
(35) *Nouvelles Annales de la Construction,* Paris, France.
(36) *Cornell Civil Engineer,* Ithaca, N. Y.
(37) *Revue de Mécanique,* Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways,* Paris, France.
(39) *Technisches Gemeindeblatt,* Berlin, Germany, 0, 70m.
(40) *Zentralblatt der Bauverwaltung,* Berlin, Germany, 60 pfg.
(41) *Electrotechnische Zeitschrift,* Berlin, Germany.
(42) *Proceedings,* Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées,* Paris, France.
(44) *Journal,* Military Service Institution, Governors Island, New York Harbor, 50c.
(45) *Coal Age,* New York City, 10c.
(46) *Scientific American,* New York City, 15c.
(47) *Mechanical Engineer,* Manchester, England, 3d.
(48) *Zeitschrift,* Verein Deutscher Ingenieure, Berlin, Germany, 1, 60m.
(49) *Zeitschrift für Bauwesen,* Berlin, Germany.
(50) *Stahl und Eisen,* Düsseldorf, Germany.
(51) *Deutsche Bauzeitung,* Berlin, Germany.
(52) *Rigasche Industrie-Zeitung,* Riga, Russia, 25 kop.
(53) *Zeitschrift,* Oesterreichischer Ingenieur und Architekten Vereines, Vienna, Austria, 70h.
(54) *Transactions,* Am. Soc. C. E., New York City, $12.
(55) *Transactions,* Am. Soc. M. E., New York City, $10.
(56) *Transactions,* Am. Inst. Min. Engrs., New York City, $6.

(57) *Colliery Guardian,* London, England, 5d.
(58) *Proceedings,* Engrs.' Soc. W. Pa., 2511 Oliver Bldg., Pittsburgh, Pa., 50c.
(59) *Proceedings,* American Water-Works Assoc., Troy, N. Y.
(60) *Municipal Engineering,* Indianapolis, Ind., 25c.
(61) *Proceedings,* Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Drop Forger,* Thaw Bldg., Pittsburgh, Pa., 10c.
(63) *Minutes of Proceedings,* Inst. C. E., London, England.
(64) *Power,* New York City, 5c.
(65) *Official Proceedings,* New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Gas Journal,* London, England, 6d.
(67) *Cement and Engineering News,* Chicago, Ill., 25c.
(69) *Der Eisenbau,* Leipzig, Germany.
(71) *Journal,* Iron and Steel Inst., London, England.
(71*a*) *Carnegie Scholarship Memoirs,* Iron and Steel Inst., London, England.
(72) *American Machinist,* New York City, 15c.
(73) *Electrician,* London, England, 18c.
(74) *Transactions,* Inst. of Min. and Metal., London, England.
(75) *Proceedings,* Inst. of Mech. Engrs., London, England.
(76) *Brick,* Chicago, Ill., 20c.
(77) *Journal,* Inst. Elec. Engrs., London, England, 5s.
(78) *Beton und Eisen,* Vienna, Austria, 1, 50m.
(79) *Forscherarbeiten,* Vienna, Austria.
(80) *Tonindustrie Zeitung,* Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen,* Wiesbaden, Germany.
(83) *Gas Age,* New York City, 15c.
(84) *Le Ciment,* Paris, France.
(85) *Proceedings,* Am. Ry. Eng. Assoc., Chicago, Ill.
(86) *Engineering and Contracting,* Chicago, Ill., 10c.
(87) *Railway Engineering and Maintenance of Way,* Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.
(89) *Proceedings,* Am. Soc. for Testing Materials, Philadelphia, Pa., $5.
(90) *Transactions,* Inst. of Naval Archts., London, England.
(91) *Transactions,* Soc. Naval Archts. and Marine Engrs., New York City.
(92) *Bulletin,* Soc. d'Encouragement pour l'Industrie Nationale, Paris, France.
(93) *Revue de Métallurgie,* Paris, France, 4 fr. 50.
(95) *International Marine Engineering,* New York City, 20c.
(96) *Canadian Engineer,* Toronto, Ont., Canada, 10c.
(98) *Journal,* Engrs. Soc. Pa., Harrisburg, Pa., 30c.
(99) *Proceedings,* Am. Soc. of Municipal Improvements, New York City, $2.
(100) *Professional Memoirs,* Corps of Engrs., U. S. A., Washington, D. C., 50c.
(101) *Metal Worker,* New York City, 10c.
(102) *Organ für die Fortschritte des Eisenbahnwesens,* Wiesbaden, Germany.
(103) *Mining and Scientific Press,* San Francisco, Cal., 10c.
(104) *The Surveyor and Municipal and County Engineer,* London, England, 6d.
(105) *Metallurgical and Chemical Engineering,* New York City, 25c.
(106) *Transactions,* Inst. of Min. Engrs., London, England, 6s.
(107) *Schweizerische Bauzeitung,* Zürich, Switzerland.
(108) *Southern Machinery,* Atlanta, Ga., 10c.
(109) *Journal,* Boston Soc. C. E., Boston, Mass., 50c.
(110) *Journal,* Am. Concrete Inst., Philadelphia, Pa., 50c.
(111) *Journal of Electricity, Power and Gas,* San Francisco, Cal., 25c.
(112) *Internationale Zeitschrift für Wasser-Versorgung,* Leipzig, Germany.
(113) *Proceedings,* Am. Wood Preservers' Assoc., Baltimore, Md.
(114) *Journal,* Institution of Municipal and County Engineers, London, England, 1s. 6d.
(115) *Journal,* Engrs.' Club of St. Louis, St. Louis, Mo., 35c.
(116) *Blast Furnace and Steel Plant,* Pittsburgh, Pa., 15c.

LIST OF ARTICLES

Bridges.

Centre Street Bridge, Calgary, Alberta.* George W. Craig. (5) Jan.–June.
Pneumatic Caisson Work for the Foundations of the Petitcodiac River Bridge Piers, at Moncton, N. B.* E. M. Archibald. (5) Jan.–June.
Philadelphia Bridges, Past, Present, and Future.* Wilmer Z. Kline. (2) Aug.
Completion of the Quebec Bridge.* (18) Sept. 29.

Electrical.

The Mathematical Treatment of the Magnetomotive Force of Armature Windings.* B. Hague. (77) July.
The Magnetic Shielding of Large Spaces.* Ernest Wilson. (77) July.
Pressure Drop Curves for Copper Overhead Lines.* G. N. Wright. (77) July.
Transmission Line Design.* F. K. Kirsten. (42) Aug.

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* Illustrated.

Electrical—(Continued).

Value of Fuel Economy in the Power Plant.* Reginald Trautschold. **(9)** Aug.

Notes on the Electric Storage Battery.* Edward Wanton Smith. (Read before the Philadelphia Section of the Am. Chemcal Soc.) **(2)** Sept.

Design, Construction and Tests of an Artificial Power Transmission Line for the Telluride Power Company of Provo, Utah.* George H. Gray. **(42)** Sept.

A Recent "Union Electric" Development. John Hunter. **(115)** Sept.

Electrical Operation of Bloom Shears.* G. E. Stoltz. **(116)** Sept.

Central-Station Service. Thomas Robson Hay. **(9)** Sept.

Insuring Continuous Power Service. D. D. Ewing. **(17)** Sept. 1.

Voltage Control of Commutating—Pole Synchronous Converters.* J. L. Burnham. **(64)** Sept. 4.

Leading Plants in Evansville.* Thomas Wilson. **(64)** Sept. 4.

On the Wave-Lengths and Radiation of Loaded Antennæ. Balth. Van Dier Pol. (Abstract of paper read before the Physical Soc. of London.) **(73)** Sept. 7.

Tests on Oil Switches.* Georg Stern and Josef Biermanns. (Abstract of article in *Elektrotechnische Zeitschrift,* Nos. 46 and 47, Vol. 37.) **(73)** Sept. 7.

Repetitions of E. M. F. in Armature Windings.* C. C. Hawkins. **(73)** Sept. 7.

The Modernization of Stuart Street Generating Station, Manchester. **(26)** Sept. 7.

Costs in Electric Furnace Operation. F. T. Snyder. (Abstract of paper in *Electrical Review.*) **(26)** Sept. 7.

Power Plant of the Rialto Building.* A. J. Dixon. **(64)** Sept. 11.

The Protection of Cables Against Electrolysis. (Abstract of article in *Annales des Postes, Télégraphes et Téléphones.*) **(73)** Sept. 14.

The High-Tension Magneto with Special Reference to the Ignition of Aeroplane Engines.* A. P. Young. (Abstract of paper read before the Aeronautical Soc.) **(73)** Sept. 14.

Electrodes for Electric Furnaces: Their Manufacture, Properties, and Utilization. **(26)** Sept. 14.

Electricity Supply at Redditch.* **(73)** Sept. 14.

Electricity at the Bunker Hill & Sullivan.* A. H. Halloran. **(111)** Sept. 15.

Fires in Transformers. M. A. Walker. **(64)** Sept. 18.

Manufacture of Electric Motors.* C. W. Starker. **(72)** Serial beginning Sept. 20.

On the Calculation of the Coupling Coefficient of Two Coaxial Flat Spiral Coils.* P. Baillie. **(73)** Sept. 21.

The Barcelona Traction, Light and Power Company.* A. Huguenin. **(11)** Sept. 21.

The Pliotron Oscillator.* **(26)** Sept. 21.

The Pressure of the Trolley on the Overhead Wire.* E. Stocker. **(73)** Sept. 21.

High-Tension Current in Mines.* J. R. Brown. (From paper read before the Kentucky Min. Inst.) **(57)** Sept. 21.

A New High-Tension Meter.* P. F. Dufour. (Abstract of paper in *Rev. Gén. de l'Electricité.*) **(26)** Sept. 21.

Magnet-Type Elevator Controller.* J. Gintz, Jr.* **(64)** Sept. 25.

The Limitation of Short-Circuit Currents in the Power Station at Golpa.* G. Klingenberg. (Abstract of article in *Elektrotechnische Zeitschrift,* No. 50, 1916.) **(73)** Sept. 28.

Curiosities of Early Mains Work. G. W. Stubbings. **(26)** Sept. 28.

Direct-Current Balancers.* W. A. E. M. **(26)** Sept. 28.

Effect of Barometric Pressure on Temperature Rise of Self-Cooled Transformers.* V. M. Montsinger. **(73)** Sept. 28.

Some Practical Experiences with Tough Rubber Compound Cables. W. Ellerd-Styles. **(26)** Sept. 28.

British Westinghouse Turbo-Alternators.* **(73)** Sept. 28.

Construction and Test of Two-Section Steel Pole.* W. C. Lancaster. **(17)** Sept. 29.

Marine.

History of the Boston Dry Dock. James W. Rollins. **(109)** Sept.

Industrial Management Principles in Shipyard Practice.* Wm. M. Kennedy. **(9)** Sept.

American Standard Single-Screw Steel Steamships.* (From *International Marine Engineering.*) **(11)** Sept. 7.

On the Analysis of the Results of Inclining Experiments.* C. Frodsham Holt. **(11)** Sept. 28.

The Failure of Boiler Plates in Service, and Investigation of the Stresses that Occur in Riveted Joints.* E. B. Wolff. (Abstract of paper read before the Iron and Steel Inst.) **(11)** Sept. 28.

Mechanical.

Reclaiming the Scrap Pile.* R. P. Crawford. **(9)** Aug.

Installing Equipment in Concrete Buildings.* H. Colin Campbell. **(9)** Aug.

Layout of Machine Tools for a Large Light Manufacturing Plant.* David J. Matlack. **(2)** Aug.

Chemical Engineering Aspect of Renovating a Sulphide Mill.* Hugh K. Moore. (Paper read before Am. Inst. of Chemical Engrs.) **(105)** Aug. 1.

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* Illustrated.

Mechanical—(Continued).

The New Carbonizing Plant at Macon, Ga.* S. Bent Russell. **(83)** Aug. 1.
An Open Construction of Carbonizing Plant at Macon, U. S. A.* **(66)** Aug. 28.
Manufacture of Nitrate of Ammonia by Electric Power at Coke-Oven Plants. E. Kilburn Scott. (Abstract of paper read before Coke-Oven Managers' Assoc.) **(66)** Aug. 7; **(26)** Sept. 7.
Intermittent Vertical Retorts for Medium-Sized and Small Gas Undertakings.* F. G. Ambler. (Abstract of paper read before the Irish Assoc. of Gas Managers.) **(66)** Aug. 14.
Suggested Improvements in the Manufacture of Silica Brick.* C. E. Nesbitt and M. L. Bell. (Abstract of paper read before the Am. Soc. for Testing Materials.) **(105)** Aug. 15; **(116)** Sept.
Prices of Gas to Different Classes of Consumers. J. E. McLeod. (Abstract of paper read before the Missouri Assoc. of Public Utilities.) **(66)** Aug. 21.
The "Direct" Process for the Manufacture of Sulphate of Ammonia.* W. S. Curphey. **(66)** Aug. 28.
A Study of Graphite and of Its Compounds for Lubricating Purposes. Christopher H. Bierbaum. **(55)** Sept.
Plant of the Standard Portland Cement Co., Leeds, Ala.* **(67)** Sept.
Rolls for Edging Flat Bar Iron or Steel.* W. S. Standiford. **(116)** Sept.
Nickel-Chrome Forgings for U. S. Weapons.* A. W. Peterson and H. E. Parkison. **(62)** Sept.
Elements of Roll Pass Design.* W. Trinks. **(116)** Sept.
Some Suggestions on Thermit Welding.* J. F. Perrith. **(62)** Sept.
Process of Forming Separator Screw Disc. **(62)** Sept.
Fallacies Regarding Malleable Iron.* A. H. Weston. **(25)** Sept.
Conserving 80 000 000 Pounds of Industrial Wastes a Year.* W. Rockwood Conover. **(9)** Sept.
Coal By-Products and the War. A. S. Knowles. **(115)** Sept.
Boiler-House Design.* Herbert E. Birch. **(9)** Serial beginning Sept.
The Use and Abuse of Steel for Aircraft.* R. K. Bagnall-Wild and W. W. Birch. **(62)** Sept.
Design of Heavy Helical Springs.* G. S. Chiles and R. G. Kelley. **(25)** Sept.
Adapting the Motor Truck to Its Work.* **(67)** Sept.
Uniflow-Engine Automatic Exhaust Valve.* **(64)** Sept. 4.
The Chemistry of Coal. M. Rouland. (Abstract of translation of address before the Société Technique du Gaz en France, published in *Journal des Usines à Gaz.*) **(66)** Sept. 4.
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McEwen High-Compression Oil Engine.* **(64)** Sept. 4.
Airplane Engine Repairs at Toronto. Fred H. Colvin. **(73)** Sept. 6.
Spot Welding at the Chalmers Plant.* **(72)** Sept. 6.
The Panama Canal Forge Shops.* Frank A. Stanley. **(72)** Sept. 6.
Design and Use of Twisted Spur Gears.* L. D. Hayes. **(72)** Sept. 6.
The Refractory Properties of Silica Bricks. H. H. Le Chatelier and B. Bogitch. (Paper read before the Académie des Sciences.) **(57)** Sept. 7.
Operation of Diaphragm Radiator Valves.* F. A. De Boos. **(101)** Sept. 7.
The Dehydration of Tar.* G. H. Sharples. (Abstract of paper read before North British Assoc. of Gas Managers.) **(66)** Sept. 11.
Low-Temperature Distillation of Inferior Coals.* T. F. Winmill. **(66)** Sept. 11.
Improved Efficiency Turbine.* **(64)** Sept. 11.
Continuous Vertical Retorts in a Fifty-Million Works. H. G. Ritchie. (Abstract of paper read before North British Assoc. of Gas Managers.) **(66)** Sept. 11.
Building a Precision Lathe.* M. E. Hoag. **(72)** Sept. 13.
The Care and Upkeep of Band-Saws.* **(72)** Sept. 13.
Application and Use of the Booking Type of Core Box.* J. V. Hunter. **(72)** Sept. 13.
Coal Gas for Motor Vehicles.* **(12)** Sept. 14.
Some Notes on Nitrating Kettles with an Example of Acetylation Apparatus.* Frederick Pope. **(105)** Sept. 15.
A Gas-Fired Welding Furnace Installation.* Charles E. Richardson. **(105)** Sept. 15.
The Synthesis of Ammonia and the Oxidation of Ammonia to Nitric Acid. Edward B. Maxted. **(105)** Sept. 15.
An Experiment in Scrubbing Carburetted Water Gas for Recovering Aromatics.* Robert J. Moore and Gustav Egloff. **(105)** Sept. 15.
Smoke Reduction in Boiler Furnaces.* Joseph Goder. **(64)** Sept. 18.
Draft in Boiler Practice.* H. F. Lawrence. **(64)** Sept. 18.
Mean Effective Pressure of Ammonia Compressors.* Carl J. Jefferson. **(64)** Sept. 18.
Efficiencies of Steam-Turbine Cycles.* C. F. Hirshfeld.* **(64)** Sept. 18.
Relation of Press Stroke to the Life of a Die.* E. F. Creager. **(72)** Sept. 20.
Location of Cam Followers.* Arthur B. Babbitt. **(72)** Serial beginning Sept. 20.
Elements of Gagemaking.* C. A. Macready. **(72)** Sept. 20.
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On the Critical Speeds of Loaded Shafts.* Wm. M. Wallace. **(12)** Sept. 21.

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* Illustrated.

Mechanical—(Continued).

Notes on the Present Knowledge and Practice in Regard to the Briquetting of Iron Ores.* Guy Barrett and T. B. Rogerson. **(11)** Sept. 21; **(12)** Sept. 28.
The Status and Prospect of Gas Lighting. W. J. Serrill. **(66)** Sept. 25.
Starting the Curtis Vertical Turbine.* **(64)** Sept. 25.
The Fay Automatic Ring-Gear Machine.* **(72)** Sept. 27.
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The Manufacture of Hardened Thread Gauges.* G. Doorakkers. **(12)** Sept. 28.
Coal Briquetting: with Special Reference to Anthracite Coal. J. A. Yeadon. (Abstract of paper read before South Wales Inst. of Engrs.) **(57)** Sept. 28.
Principles and Methods of a New System of Gas Firing.* A. C. Ionides. (Paper read before the Inst. of Metals.) **(11)** Sept. 28; **(66)** Sept. 25.
Heat Treatment of Carburized Parts. W. C. Peterson. **(62)** Oct.
Correcting Faulty Forge Construction.* James C. Cran. **(62)** Oct.
The Evolution of the Forging Press.* Frank I. Ellis. **(62)** Oct.
Heat Treating and Hardening of Gears. W. H. Phillips. (Paper read before the Am. Gear Manufacturers' Assoc.) **(62)** Oct.
Organisation Scientifique de l'Usinage; Travaux de Perçage; Recherche de la Meillure Utilisation des Aciers à Outils.* P. Denis. **(33)** Serial beginning Oct. 6.
La Transformation des Huiles Minérales Lourdes en Essences et en Produits Légers. **(33)** Oct. 13.
Machines à Rainurer et à Mortaiser, Système Newton.* **(33)** Oct. 13.
Utilisation Après la Guerre des Usines Créées pour les Besoins de la Defense Nationale; Fabrication d'Objets Emboutis.* M. Lunet. **(33)** Oct. 27.
Die Schweiz. Prüfanstalt für hydrometrische Flügel Papiermühle bei Bern.* **(107)** Sept. 29.

Metallurgical.

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JANUARY, 1918

Vol. XLIV. JANUARY, 1918. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications.

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PAPERS AND DISCUSSIONS

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VERIFICATION OF THE BAZIN WEIR FORMULA BY HYDRO-CHEMICAL GAUGINGS.

By Floyd A. Nagler, Jun. Am. Soc. C. E.

To be Presented March 6th, 1918.

Synopsis.

This paper presents the results of 23 experiments on a standard Bazin weir, 3.72 ft. high and 6.56 ft. wide. The experiments were carried on in a flume built for the University of Michigan at the Argo Spillway, Ann Arbor, Mich.

The water was measured hydro-chemically, according to the methods recommended by B. F. Groat, M. Am. Soc. C. E., in his paper entitled "Chemi-Hydrometry and Its Application to the Precise Testing of Hydro-Electric Generators."*

Tests were made on heads as high as 4 ft. on the weir, thus extending the application of the weir formulas more than 100 per cent.

This paper describes briefly the method of hydro-chemical and weir gauging used in the experiments.

Introduction.

Volumetric experiments on the flow of water over sharp-crested weirs have been performed for only a comparatively small range in head on the weir. M. Bazin's experiments cover a range in head from 0.194 to 1.780 ft.; those of the late J. B. Francis, Past-President, Am.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

* *Transactions*, Am. Soc. C. E., Vol. LXXX, p. 951.

Soc. C. E., are included between 0.736 and 1.060 ft.; and the experiments of Messrs. Fteley and Stearns are between 0.0735 and 1.6038 ft.

These experimenters were unable to use higher heads due to the fact that their volumetric measuring basins filled too rapidly with the larger quantities of water which flowed over the weir at high heads. Nevertheless, these few experiments, within so small a range in head, were used by each experimenter in evaluating the coefficients for the standard weir formulas which bear their names.

For lack of a better basis of computation, engineers have been continually forced to apply the Bazin, Francis, and Fteley and Stearns formulas in the solution of problems involving heads on the weir many times that of the maximum on which any of these formulas are based.

Considerable might be written on the discrepancies (of as much as 3%) which exist between the three formulas for some heads of less than 2 ft.; but nothing is known of the possible differences which may exist for higher heads. Without further experiments, covering a wider range in head, these formulas cannot be applied with security in the computation of discharge in case the head falls outside those limits on which each respective formula is based.

Within the past decade the hydro-chemical method of gauging large quantities of water, originally used by some Swiss engineers, has been introduced into the United States. In 1914 Mr. Groat applied this method with considerable accuracy in testing hydro-electric generators, where quantities of water as large as 1 500 cu. ft. per sec. had to be measured. He published the results of these tests, together with an exhaustive treatment of the theory of salt-solution gauging, in his paper, "Chemi-Hydrometry and Its Application to the Precise Testing of Hydro-Electric Generators". In this paper Mr. Groat describes a method of "salt-solution gauging" for which he claims an accuracy that could only be attained by the most precise volumetric measurements. This method might easily be applied in gauging the flow of water over a weir, thus checking the existing volumetric experiments and extending the present experimental data to higher heads.

Contemplating the performance of such a set of experiments, an experimental flume was constructed at the Argo Spillway, Ann Arbor, Mich., for the University of Michigan, by the Detroit Edison Company. In the construction of this flume, it was decided to duplicate the conditions of the Bazin experiments, with additional capacity sufficient to obtain heads on the weir (3.72 ft. high and 6.56 ft. long) as high as 4 ft. The proposed experiments could then be compared with an accepted standard weir formula and its basic experiments.

The experiments were performed between March 24th and May 2d, 1917.

Bazin's Experiments and Formula.

Bazin began his extensive weir experiments in 1886 on the Canal de Bourgogne, near Dijon, France. The weirs were constructed in a channel 6.56 ft. (2 m.) wide. Contractions were suppressed. The crest itself was made of an iron plate. Of these experiments 67 were performed on a weir 3.72 ft. high and 6.56 ft. wide, including heads up to 1.012 ft.; 38 on a weir 3.27 ft. high and 3.28 ft. long, with heads up to 1.34 ft.; and 48 on a weir 3.297 ft. high and 1.64 ft. long, including heads up to 1.780 ft. Having calibrated his standard weir within at least 1% by volumetric measurements, M. Bazin proceeded to perform experiments on weirs of different heights at places down stream in the same channel. From the results of these observations, he evaluated the coefficients for his formula. If H is the measured head on the weir, p the height of the weir, and L the length of the weir crest, then Q, the discharge in cubic feet per second, is expressed as follows:

$$Q = \left(0.405 + \frac{0.00984}{H}\right)\left(1 + 0.55\frac{H^2}{(p + H)}\right) L\,H\sqrt{2\,g\,H}$$

If the salt-solution method of gauging in the proposed experiments checks the volumetric measurements of flow over the weir throughout the range of the Bazin experiments, there is then established a basis for measuring accurately the water flowing over the weir, and the range of application of the weir formula becomes extended.

Chemi-Hydrometry.

The process of measuring the quantity of a liquid by observing the dilution that a solution of some chemical undergoes in being thoroughly mixed with that liquid, has been called "chemi-hydrometry."

For example, let 10 lb. of salt be thoroughly dissolved in a tank of water. If, on chemical analysis, it is found that each cubic foot of this water contains 1 lb. of salt, the volume of water in the tank is equal to the ratio of dilution of the salt, or 10 cu. ft. Or, suppose that a salt solution is introduced into a flowing stream at the rate of 1 cu. ft. per sec. If this salt solution contains 10 lb. of salt per cubic foot, and it is found that each cubic foot of the flowing water, after being mixed with the salt solution, contains 1 lb. of salt, then the rate of flow of the stream is represented by the "ratio of dilution" of the salt solution, multiplied by the rate at which that solution is introduced into the stream; or, in this case, 10 cu. ft. per sec.

These examples give the essence of the theory of hydro-chemical gauging. In practice, however, other factors enter, which produce many complications. For a full treatment of errors and complications which arise, reference should be made to the paper by Mr. Groat previously referred to. The following brief treatise on the subject is offered in order to save the reader the labor of reading and mastering Mr. Groat's voluminous paper, since only that part of the theory is presented which will be necessary for an understanding of the methods used in these experiments. The symbols and definitions used by Mr. Groat have been adopted throughout.

In most cases the normal water contains an initial quantity of salt in solution; this must be taken into consideration, in order to make a correct gauging. Corrections must also be applied in comparing solutions of unlike temperatures. In some cases, cognizance must be taken of the fact that, when two solutions with different percentages of salt in solution are mixed, the total volume is less than the sum of the volumes of the two initial constituent solutions. This shrinkage in volume is taken into consideration by applying a coefficient, k, to the stronger solution, such that the volume of the weaker solution plus the volume of the stronger solution multiplied by k is equal to the volume of the resultant mixture.

The method of "special dilutions" and "balanced evaporations" was adopted in making the salt analysis in these tests. This method simply implies that a special dilution of the salt solution sample with the normal water sample is made in the laboratory. Effort is made to have the "ratio of dilution" of this special dilution approximate the estimated ratio of dilution during the test. This special dilution receives the same method of treatment in the laboratory as the dosed water samples.

Definitions and Equations.—The "ratio of mixture" is the ratio of the quantity of the weaker of two solutions to the quantity of the other solution with which it is mixed. It is represented by r.

The "ratio of dilution" is the ratio of the quantity resulting from the mixture of two salt solutions of different percentages to the quantity having the higher percentage. It is represented by R.

When a solution is referred to as "being of a certain percentage" it is meant that this percentage of the total weight of the solution is dry salt. It is represented by p.

By "concentration of solution" is meant the weight of chemical in solution per unit of volume. It is represented by c.

Then, let Q_1 = the quantity of water flowing in the stream;
q = the rate of discharge of the salt solution;
Q_2 = the quantity of water flowing in the stream after the introduction of the salt solution;
k = the coefficient of shrinkage of the salt solution; and
c_1, c, c_2 = the concentrations of the normal water, salt solution, and dosed flume water, respectively.

If all the solutions are at the same temperature; or, if originally at different temperatures, temperature corrections have been previously applied, then

$Q_1 c_1$ = the weight of salt in the normal water; qc = the weight of salt in the salt solution; and $Q_2 c_2$ = the weight of salt in the mixture.

Hence,
$$Q_1 c_1 + q\,c = Q_2 c_2 \quad \ldots\ldots (1)$$

Also, by definition,
$$Q_1 + k\,q = Q_2 \quad \ldots\ldots (2)$$

Likewise,
$$\frac{Q_1}{q} = r$$

and,
$$\frac{Q_2}{q} = R$$

By substitution in Equation (1)
$$rc_1 + c = Rc_2 \quad \ldots\ldots (3)$$

By substitution in Equation (2)
$$r + k = R \quad \ldots\ldots (4)$$

By substituting Equation (4) in Equation (3), we obtain,
$$rc_1 + c = rc_2 + kc_2$$

Whence, solving for r, we obtain,
$$r = \frac{c - kc_2}{c_2 - c_1} \quad \ldots\ldots (5)$$

Also, solving for c_1, we obtain,
$$c_1 = \frac{rc_2 + kc_2 - c}{r} \quad \ldots\ldots (6)$$

Equation (5) may be applied when the method of special dilutions is not used. It is applicable when the normal water, dosed water, and salt-solution sample are analyzed directly.

However, let a special dilution be made up in the laboratory, using the actual salt-solution sample with the concentration, c, and the normal pond water with the concentration, c_1. The ratios of mixture and dilution should approximate r and R, respectively, but actually have values of r' and R'. The final dilution has a concentration c'_2, approximating c_2. Then, by analogy, we may write, from Equation (6),

$$c_1 = \frac{r'c'_2 + kc'_2 - c}{r'}$$

In this equation, r must approximate r' so closely that the coefficient of shrinkage is the same for both dilutions.

Equations (6) and (7), however, may be placed equal to each other.

$$\frac{r'c'_2 + kc'_2 - c}{r'} = \frac{rc_2 + kc_2 - c}{r}$$

Solving for r, we obtain

$$r = \frac{r'}{\frac{c - r'c_2 - r'c'_2 - kc'_2}{c - kc_2}}$$

By analogy, from Equation (4), however, $r' = R' - k$. Substituting this value of r' in the denominator of the previous expression, we obtain

$$r = \frac{r'}{1 + R'\frac{c_2 - c'_2}{c - kc_2}}$$

Thus, $$Q_1 = qr = q\frac{r'}{1 + R'\frac{c_2 - c'_2}{c - kc_2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots(8)$$

This equation is of practical application. It should be observed that c_1 has been eliminated; hence, it is unnecessary to analyze the normal pond water for its saline content. It has been stated that the use of this equation requires the previous correction of the volume of every solution handled throughout the entire laboratory process, reducing every sample analyzed in each experiment to some common temperature.

The reagent used in salt analysis is silver nitrate. This chemical is dissolved in distilled water in some standard proportions. Then a measured quantity of this silver nitrate solution is used, sufficient to neutralize exactly all the salt in a given sample. The molecular weight of silver nitrate is 170; that of sodium chloride (common salt) is 58.5. Hence, 1 gramme of silver nitrate will neutralize $\frac{58.5}{170} = 0.3441$ grammes of salt. Thus, if the quantity of anhydrous silver nitrate contained in the silver nitrate solution used in a titration is known, the quantity of anhydrous salt contained in the sample is 0.3441 times this quantity.

If all titrations require about the same quantity of silver nitrate solution, and all samples, prepared for analysis, are of the same character and volume, and if the same quantity of indicator is used to indicate the end point of the reaction for each sample, then, for practical purposes, we may write,

$$c = \propto t,$$

where t is the volume of the silver nitrate solution required to titrate a unit volume of the sample, and α is a constant dependent on the concentration of the standard silver nitrate solution, and the actual equivalent between the silver nitrate and the sodium chloride. Hence, we may write with practically (not theoretically) no error,

$$Q_1 = q\, r = q \frac{r'}{1 + R' \frac{t_2 - t'_2}{t - k\, t_2}} \dots\dots\dots\dots\dots\dots\dots (9)$$

Thus, if silver nitrate of the same strength is used for all titrations in a single experiment, it becomes unnecessary to determine the actual salt content of the sample or the exact concentration of the silver nitrate solution. The values of t'_2 and t_2 have such a relation in the equation that when t'_2 approximates t_2, and there is then the same relative error in both titrations, this error has no effect on the practical value of r.

Therefore, in order to make a salt-solution test, three samples must be provided:

(1) A sample of the salt solution;

(2) A sample of the normal pond water; and,

(3) A sample of the dosed flume water.

The equation also designates that q, the rate of dosing, must be observed; and the laboratory process further involves the observation of the temperatures of all solutions and the calibration of all flasks and pipettes, in order that r' and R' may be calculated with accuracy.

Description of Testing Plant.

Testing Flume.—The flume in which these experiments were performed was built in September, 1916, by the Detroit Edison Company. Connecting with two of the flood-gates at the Argo Spillway, it extended 143 ft. down stream.

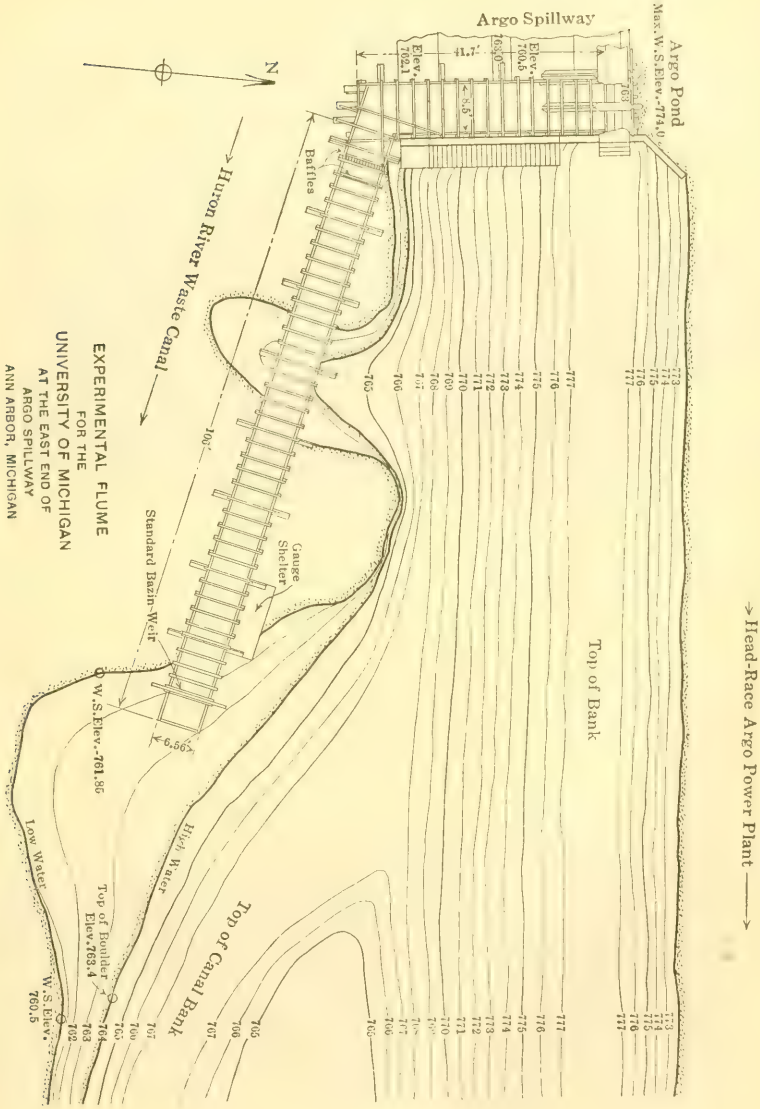
Figs. 1 to 4 show the nature of the design and the construction of the flume.

The first 40 ft. of the flume was built 8½ ft. wide and 9 ft. deep. It then became necessary to divert it in the direction assumed by the natural flow of the river, and the remaining 103 ft. was made 6.56 ft. (2 m.) wide, the width of the Bazin channel. The lining was of 2-in., matched yellow pine, with driven splines uniting every board. No effort was made to caulk these joints or fill them with white lead. After the flume had been filled with water for three days, allowing the lining to soak and expand, there was no visible leakage at any point.

Figs. 5, 6, and 7 show the flume in process of construction, and Fig. 9 is reproduced from a photograph of the finished structure.

The quantity of water entering the flume was regulated by lowering or raising the flood-gates at the spillway. The salt solution was introduced under pressure into a sprinkling system in the orifices of these gates. Due to the fact that the water entered the flume at a very high velocity, it first became necessary to lower this abnormal velocity and distribute it uniformly over the entire flume section. This was accomplished by constructing a submerged weir 3½ ft. high across the flume at a point 16 ft. down stream from the gates. In striking this obstruction at a high velocity, the water was thrown into a great commotion, passing over the weir with a fair velocity distribution, regardless of the turbulence. This weir proved an excellent mixer for the salt solution, securing practically its uniform distribution throughout the entire flume section.

As the water passed around the bend in the flume, the velocity at the outside was observed to be perceptibly higher than that on the inside. This abnormal condition was remedied by placing sets of horizontal and vertical baffles at a point 10 ft. below the bend. The



EXPERIMENTAL FLUME
FOR THE
UNIVERSITY OF MICHIGAN
AT THE EAST END OF
ARGO SPILLWAY
ANN ARBOR, MICHIGAN

FIG. 1.

baffles were constructed of 2-in. yellow pine boards, swinging on an eccentric longitudinal axis. By closing the vertical baffles at the right of the flume, a uniform distribution of velocities was again secured. Fig. 11 exhibits velocity contours taken at a point 25 ft. above the weir. These contours were obtained with an Ott current meter operating on a metal rod when there was a head of about 3 ft. on the weir.

Two floating railroad ties were placed across the flume about 28 ft. above the weir. These were efficient in reducing the small oscillatory wave motion of the water in the channel of approach.

The Weir.—The weir was built up of 4-in. timbers, as shown in the section on Fig. 4. The crest was formed by a ⅛-in. brass strip, inserted at one edge of, and flush with one face of, a 7 by ⅜-in. plate of cold-rolled steel. The brass strip was soldered and screwed to the steel plate, all recesses in the countersunk holes being filled with solder. The back face of the plate and the upper edge of the brass was then planed and finished absolutely true. This left a sharp right-angled knife-edge on the up-stream corner of the crest. The object of the brass strip was to produce a crest which would not be subject to corrosion, thus preventing the introduction of error in the weir discharge from this source. The whole plate was inserted flush with the up-stream face of the wooden timbers, and fastened to them by bolts the heads of which were countersunk in the back of the steel plate. The crest was set at an elevation of 3.72 ft. above the bottom of the flume.

Four ¾-in. bolts, 40 in. long, bound the weir timbers to the bottom of the flume. By loosening or tightening the nuts on these bolts, on either side, the weir crest was maintained absolutely level throughout the experiments.

The sides of the flume extended 6 ft. beyond the weir, but the floor extended no farther than the weir. This feature insured abundant aeration for the nappe from underneath.

The frame of the flume at the weir section was made of quadruple strength. All joints were bolted, and great care was exercised in plumbing the side posts. The timbers under the flume, at this point, rested on 4 ft. of concrete. The side posts of the frame extended for 3 ft. into the concrete. This produced a very rigid and permanent frame at the weir section. The construction is clearly shown in Fig. 4 and the erection of the frame is shown in Fig. 6.

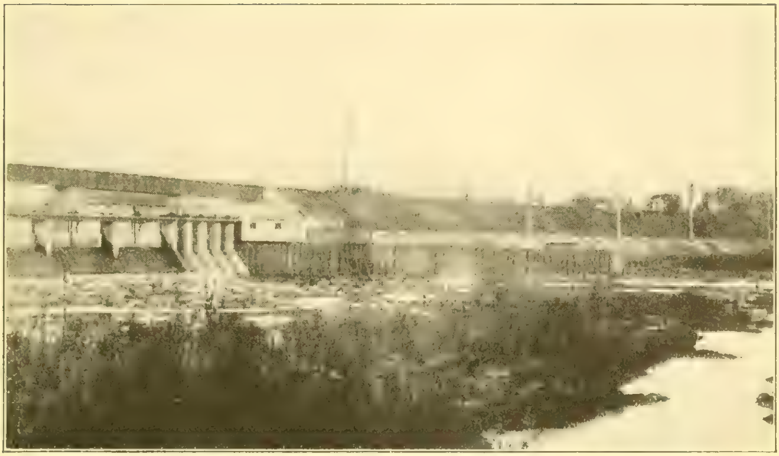


FIG. 2.—UNIVERSITY OF MICHIGAN EXPERIMENTAL FLUME.

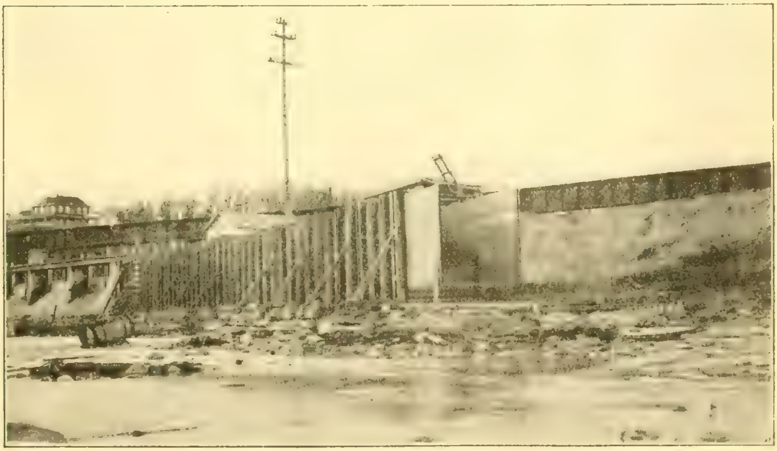
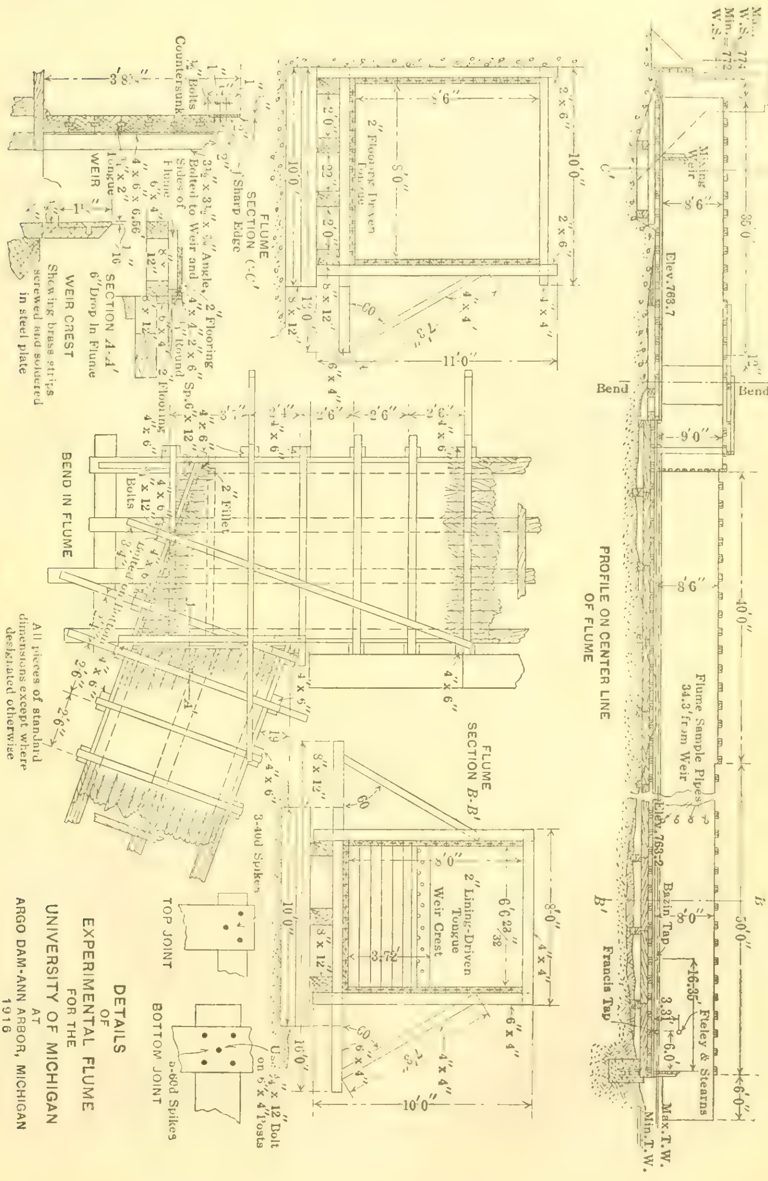


FIG. 3.—UNIVERSITY OF MICHIGAN EXPERIMENTAL FLUME.



DETAILS
OF
EXPERIMENTAL FLUME
FOR THE
UNIVERSITY OF MICHIGAN
AT
ARGO DAM-ANN ARBOR, MICHIGAN
1916

FIG. 4.

Placing the weir at the end of the flume gave it a free basin about 90 ft. in length. The bottom of the flume was level throughout this entire length.

Fig. 10 shows the weir with about 0.3 ft. of water flowing over the crest.

Hook-Gauges and Piezometer.—For all heads up to 2 ft., the head on the weir was measured simultaneously by three hook-gauges operating in galvanized tanks connected to the flume by 2-in. pipes. These pipes were attached so that the opening was flush with the inside wall of the flume. Heads of from 2 to 4 ft. were measured by a fourth hook-gauge. A piezometer tube, with a ¼-in. opening, flush with the side of the flume was also read as a check on the hook-gauge measurements.

Hook-gauge No. 1 was one of the new all-metal Gurley gauges, with a 45° point. The stilling tank for this gauge was connected to a point 6 ft. from the weir and 0.414 ft. below the weir crest. This was the point of observation used by Fteley and Stearns.

Hook-gauge No. 2 was one of the old Gurley gauges, with wooden slides and a sharp needle point. The stilling tank for this gauge was connected to a point 6 ft. from the weir and 6 in. above the bottom of the flume. This was the point of observation used by Francis.

Hook-gauge No. 3 was also one of the old Gurley gauges, with wooden slides, but it was equipped with a 45° point. The stilling tank for this gauge connected to points on both sides of the flume, 16.35 ft. from the weir and 6 in. above the floor of the flume. This was the point of observation used by Bazin.

Hook-gauge No. 4 was an all-metal hook-gauge designed especially for these experiments, and made by Eberbach and Son, of Ann Arbor, Mich.; it was found to be more satisfactory in its operation than any of the four gauges used. The stilling tank for this gauge connected with the lead pipes to Gauge No. 3.

The piezometer tube was 1½ in. in diameter, with a brass scale, graduated to 0.005 ft., mounted at its side. The tube was connected with the flume at a point 11 ft. from the weir and 6 in. below the crest.

Each gauge was provided with an electric light on a drop cord in order to assist in the observation of the reflection at the point. Gauges with the 45° point were found to be the most readily observed.

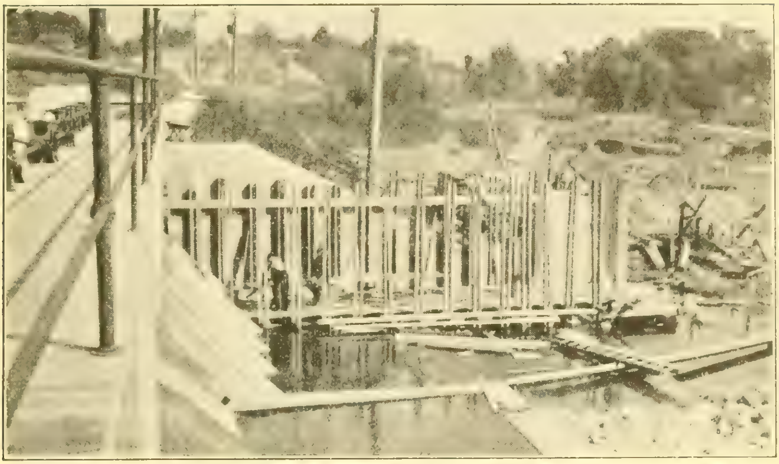


FIG. 5.—CONSTRUCTION OF FLUME.

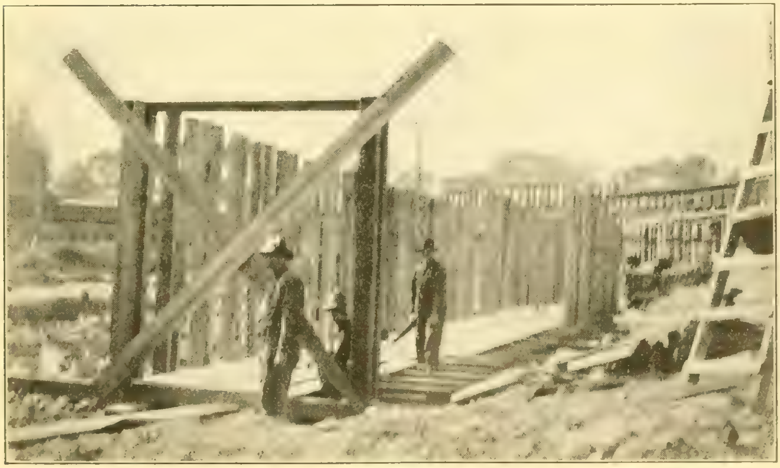


FIG. 6.—CONSTRUCTION OF FLUME.

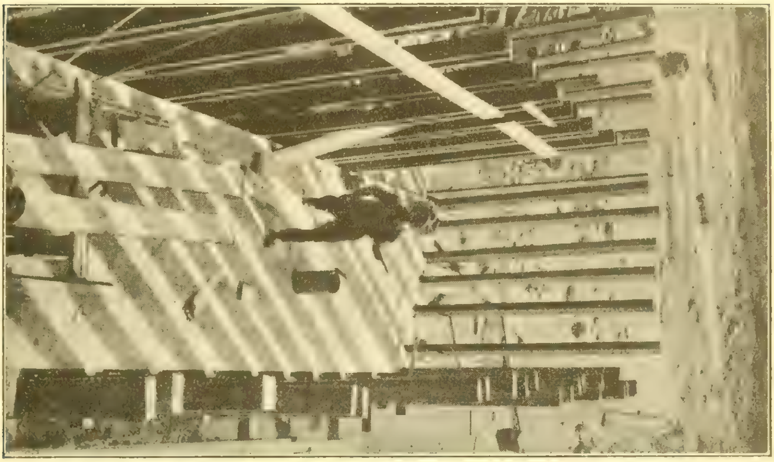


FIG. 7.—CONSTRUCTION OF FLUME.

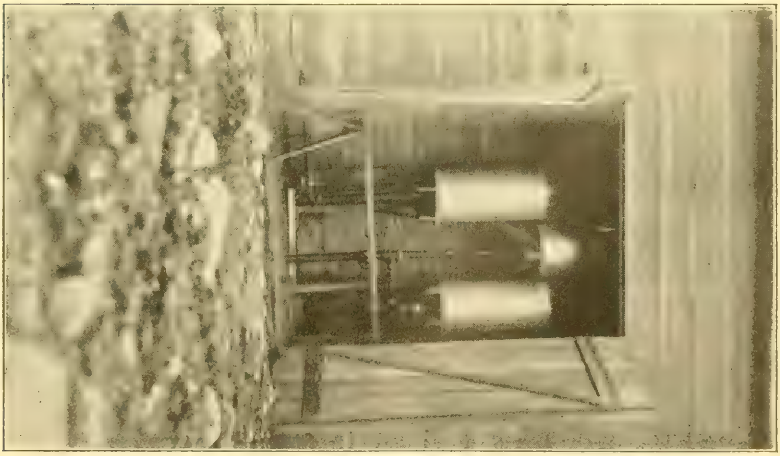


FIG. 8.—WEIR GAUGE SHELTER.

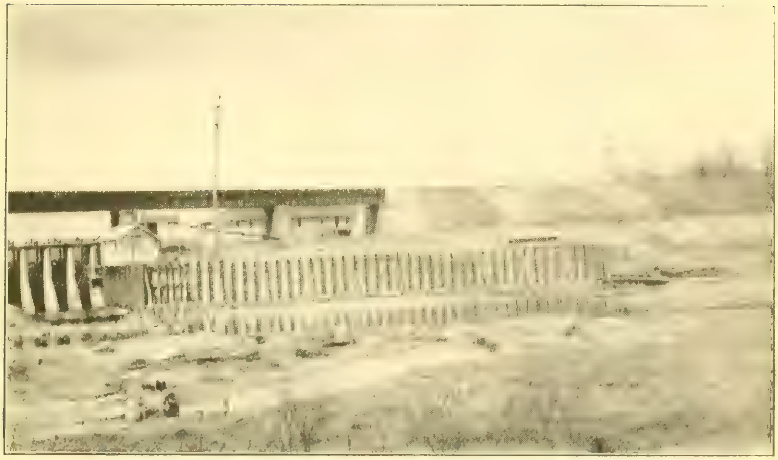


FIG. 9.—THE ARGO TESTING FLUME.

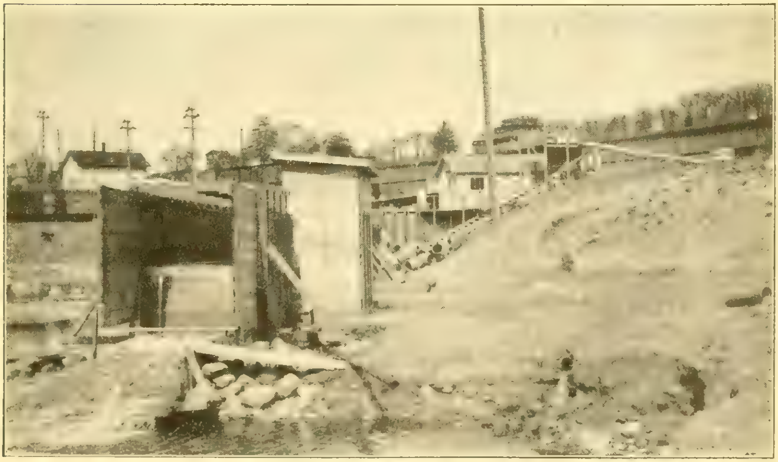


FIG. 10.—THE WEIR.

All hook-gauges were mounted on a frame of 4 by 4-in. timbers. This frame was independent of the flume, having its foundation in a mass of concrete.

The gauges were enclosed within a gauge shelter for protection. Fig. 8 shows a little of the interior of this shelter, three of the galvanized stilling tanks being plainly visible.

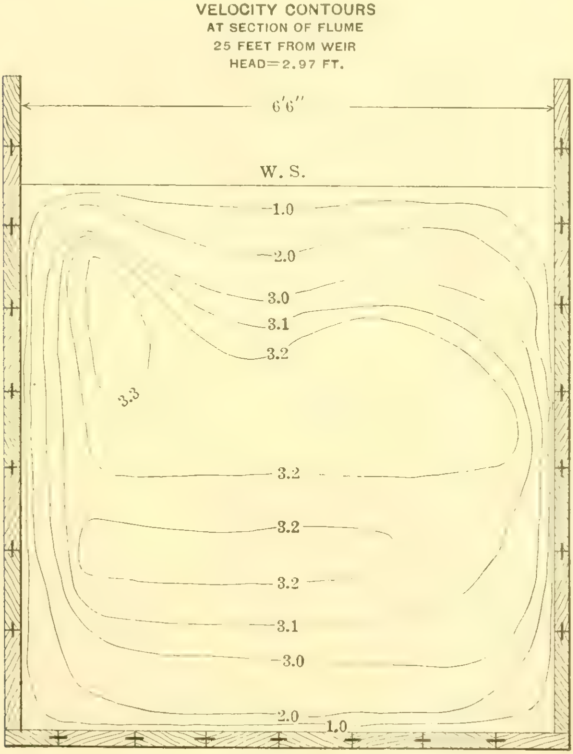


FIG. 11.

Dosing Apparatus.—In order to be able to measure a discharge over the weir as great as 200 cu. ft. per sec., by diluting a salt solution of a concentration of 300 grammes per liter, in the ratio of 6 000 to 1, during an experiment lasting 15 min., it was predetermined that a salt-solution tank with a capacity of about 50 cu. ft. would be required. This allowed 5 min. for dosing before and after each experiment, in order to insure good regulation of the dosing rate.

The solution tank is shown by Fig. 12. The tank was 4.067 by 3.33 ft. and 4 ft. deep. A piezometer was mounted on its side. The glass tube was 1 in. in diameter, and connected with the bottom of the tank. The height of the column of solution standing in the tube indicated the elevation of the solution in the tank. The gauge scale was made by Eberbach and Son. The scale had a sliding vernier attached to a mirror index. It was possible to read the water-surface elevation within 0.001 ft. with this apparatus. Fig. 13 shows the location of the solution tank and gauge.

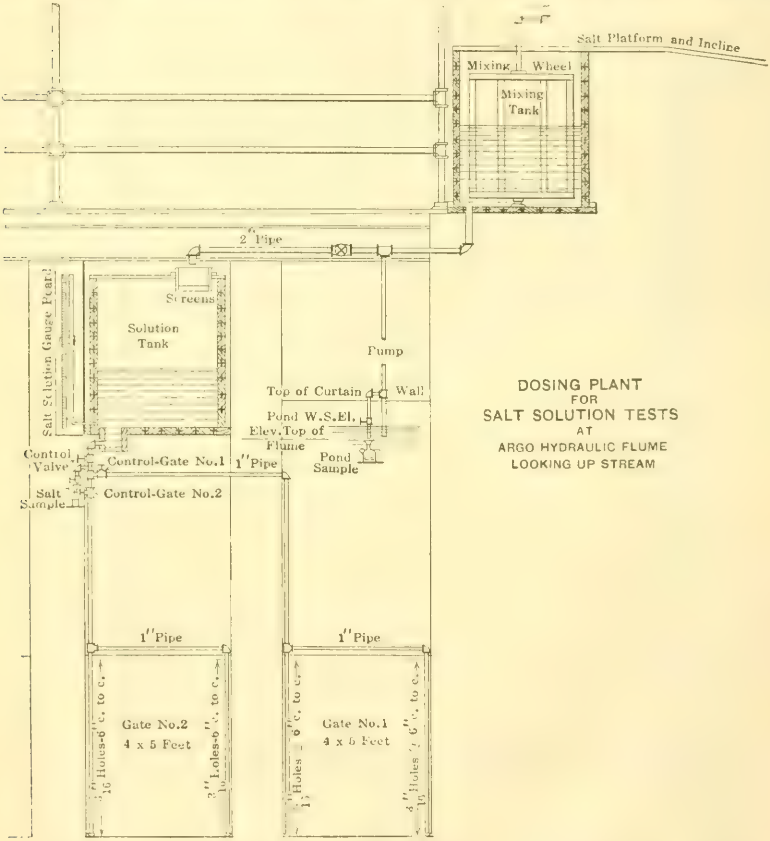


FIG. 12.

In varying the discharge of the water through the flume, from the least to the largest quantities, it was decided to use always the maximum quantity of salt solution which could be obtained from the

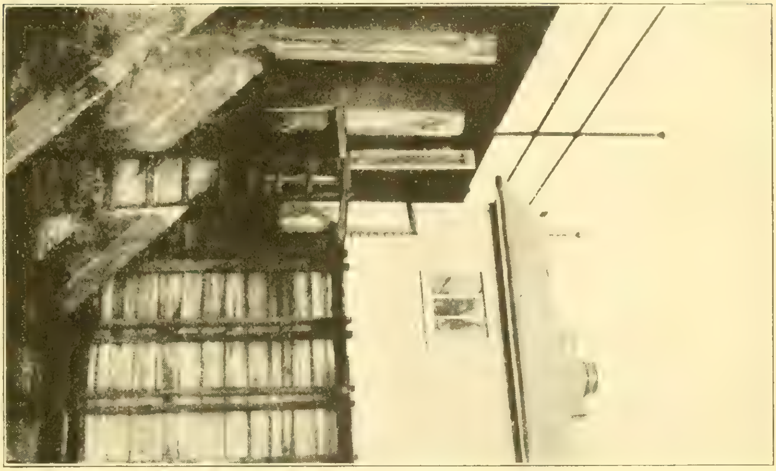


FIG. 13.—LOOKING TOWARD THE SOLUTION TANK AND PIEZOMETER.

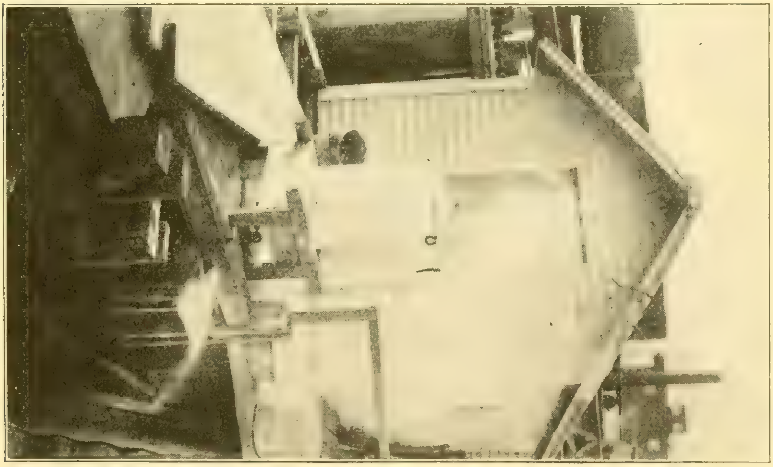


FIG. 14.—THE CALIBRATOR.

tank. This would insure a maximum difference between the initial and final readings of the piezometer, reducing to a minimum the effect of an error in the absolute reading of the piezometer scale. Hence, an endeavor was made to maintain q approximately the same for all experiments. Consequently, in order that the flume samples from all experiments might have the same concentration, it was necessary to vary the concentration of the salt solution for each experiment. The quantity of salt used varied from 1 000 lb. for the highest, to 15 lb. for the lowest, head.

Ordinary commercial salt was used. It was found to contain some foreign matter, including small chips and fine sand. This fact, combined with the requirement that no undissolved salt be present in the solution tank, necessitated first dissolving the salt in a mixing tank and then screening off all foreign matter before passing it into the solution tank. Screens of 30 and 80 meshes to the inch were used.

The mixing tank was filled with water by the pump indicated on Fig. 12. The solution of 1 000 lb. of salt was accomplished in only 40 min. with the aid of the mixing wheel inside the mixing tank.

The rate of dosing the salt solution was maintained constant throughout the entire experiment by a general control valve. Beyond this point, provision was made for drawing off a continuous sample of the salt solution through a small pipe tapping the larger discharge pipe. The salt solution could be introduced into Gate No. 1 or Gate No. 2 in any quantity desired, by the regulation of the valves in the pipes conducting it to them.

The salt solution was introduced into the orifice under the pressure head available due to the elevation of the solution tank. Distributing pipes, 1 in. in diameter, were fastened on each side of the orifice, and $\frac{3}{16}$-in. holes, 6 in. from center to center, were drilled in these pipes at an angle of about 30° down stream. These distributing pipes, combined with the submerged weir and baffles, produced a very uniform distribution of the salt solution throughout the entire flume section.

Fig. 15 shows the general plan of the entire testing plant. The mixing tank and salt platform are in the foreground.

Sampling Apparatus.—The dosed flume-water samples were taken at a section 34.3 ft. above the weir, or 108.7 ft. from the point at which the salt solution was charged into the water.

With the flume sampling apparatus, Fig. 17, two to four samples of dosed flume water were obtained from 8 to 16 points in the flume section. Each of the inclined pipes had four $\frac{3}{64}$-in. holes drilled in the upper side, 1.64 ft. apart. The discharge through each of these small orifices was "free" and practically the same throughout the length of the pipe. The water then flowed down the inclined pipe into the sample bottle at the left. The valve at the right provided means for flushing the pipe, the pet-cock above it remaining open when the pipe was not being flushed. An excess of the sample, above the predetermined rate of 1 gal. in 15 min., for which the pet-cocks at the left were set, flowed out of the pipe through the by-pass above the pet-cock. Under any head, this excess did not exceed the sampling rate.

A sample of the normal pond water was drawn from the suction pipe of the pump, as shown by Fig. 12.

Electric Bell and Salt Detection Apparatus.—There was a 5-volt battery circuit with electric bells at the solution tank and in the gauge shelter. These bells could be heard from any point on the flume. The ringing of the bells was controlled by a push-button in the laboratory.

A salt detection circuit was established in parallel with the bell circuit. The contact points, $\frac{1}{8}$ in. apart, were inside the flume, 3.5 ft. from the bottom, at the bend, at the sampling section, and at the Bazin gauging section. A milli-voltmeter in the laboratory was connected in this circuit so that it could be placed in series with any one set of contacts. With normal water flowing through the flume, the instrument registered 15 milli-volts; but when the dosed flume water reached the contacts, the pointer would swing slowly up to 19.5 milli-volts, the salt having increased the conductivity of the water. This instrument proved invaluable in determining the time interval required by the salt to travel from the point of dosing to that of sampling. From the indications of the milli-voltmeter, the "timer" could signal the sampler when the pointer showed that a uniform regime of sale dosing had been established.

Metal Calibrator.—A heavy galvanized-iron calibrator of 4.262 cu. ft. capacity, at 10.2° cent., was used in calibrating the solution tank. The calibrator had a conical bottom and top, reducing to a

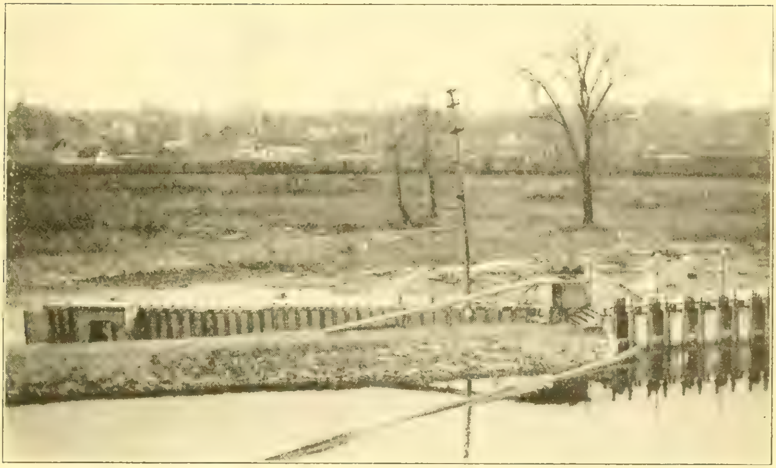


FIG. 15.—THE FLUME AND SALT-SOLUTION APPARATUS.

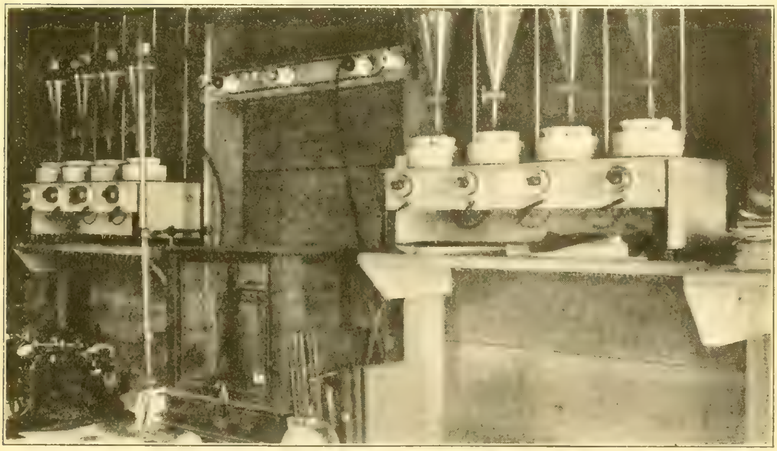


FIG. 16.—THE EVAPORATION APPARATUS.

1¼-in. pipe at each end. In principle, it was nothing more or less than a large pipette. Fig. 14 shows the calibrator standing in front of the laboratory, mounted on a wooden frame for convenient handling.

Chemical Laboratory.—A chemical laboratory, 8.5 by 18 ft., with sufficient equipment to make a salt solution analysis, was built on top of the flume near the spillway. Fig. 14 shows the entrance to the laboratory, and Fig 18 is a view of the inside, as seen from the door.

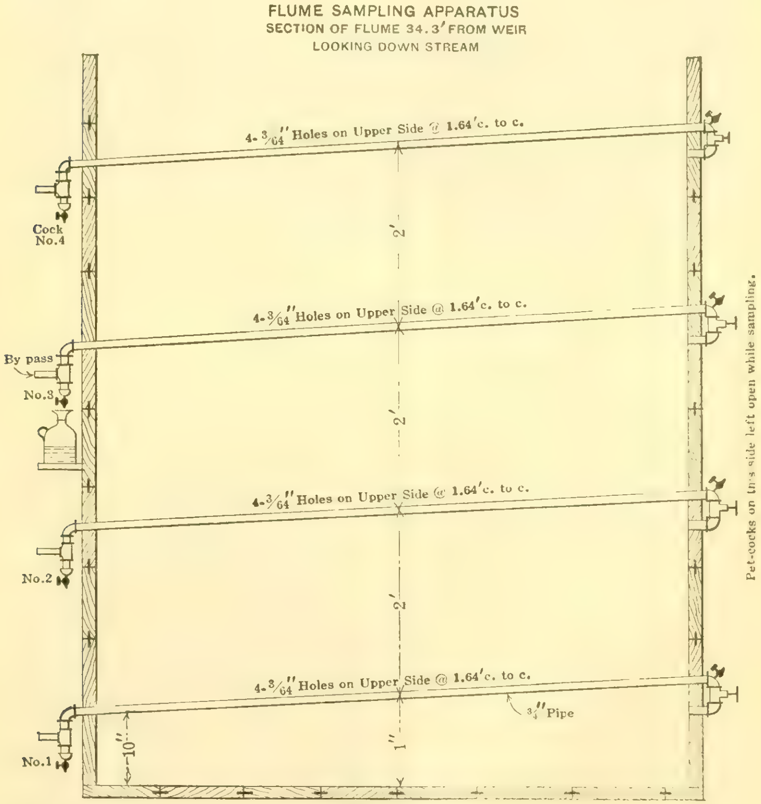

FLUME SAMPLING APPARATUS
SECTION OF FLUME 34.3′ FROM WEIR
LOOKING DOWN STREAM
4-3/64″ Holes on Upper Side @ 1.64′c. to c.
Cock No.4
2′
4-3/64″ Holes on Upper Side @ 1.64′c. to c.
By pass
No.3
2′
4-3/64″ Holes on Upper Side @ 1.64′c. to c.
No.2
2′
4-3/64″ Holes on Upper Side @ 1.64′c. to c.
3/4″ Pipe
No.1
10″
1′
Pet-cocks on this side left open while sampling.

FIG. 17.

The following is a list of the essential apparatus in the laboratory:

1 balance with weights; sensitive to 0.1 mg.
1 Fairbanks scales, of 500 lb. capacity.
2 four-unit electric evaporators.
8 one-half liter separatory funnels.

4	100-cu. cm. burettes at 20° cent.
16	No. 3 casseroles.
3	one-liter volumetric flasks.
2	500-cu. cm. volumetric flasks.
1	100-cu. cm. volumetric flasks.
3	standard thermometers from 0° to 110° cent.
3	10-cu. cm. pipettes.
1	hydrometer.
12	one-liter flasks.
62	one-gallon spring-water bottles.
20	one-quart wide-mouth bottles.
	Miscellaneous beakers, rubber stoppers, funnels, etc.

The separatory funnels, casseroles, and evaporators, as mounted during evaporation, are shown in Fig. 16. The evaporators were specially designed and manufactured for these experiments by Eberbach and Son. The heating coils were made of nichrome wire. By connecting a variable resistance in series with each unit, the heat under each casserole was regulated so as to keep the temperature of the sample just below the boiling point.

The experiments were performed so that the quantity of silver nitrate solution used in the titration of all samples would be either a little less or greater than 500 cu. cm. This required the use of 100-cu. cm. burettes, graduated to 0.1 cu. cm.

Spring-water bottles of 1-gal. capacity were used in obtaining the samples of the dosed flume water and the normal pond water. The salt sample was obtained in wide-mouthed 1-qt. bottles. When filled, all sample bottles were corked with rubber stoppers.

The hydrometer proved indispensable in checking the density of the salt solution in order to insure that all salt thrown into the mixing tank was dissolved before drawing the solution off into the solution tank.

The Fairbanks scales were used on top of the salt platform in weighing the salt to be dissolved.

Chemicals.—The chemicals used in the test were commercial salt, silver nitrate, and potassium bichromate.

A good grade of commercial salt was purchased at $1.43 per bbl. In these experiments, 50 bbl. were used.

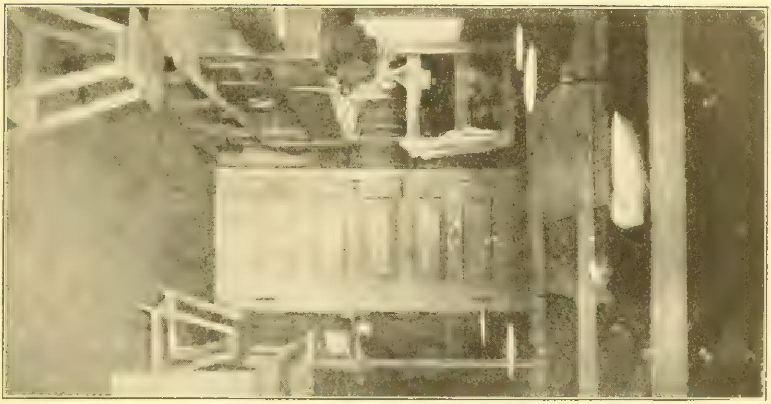


Fig. 18.—Interior of Laboratory.

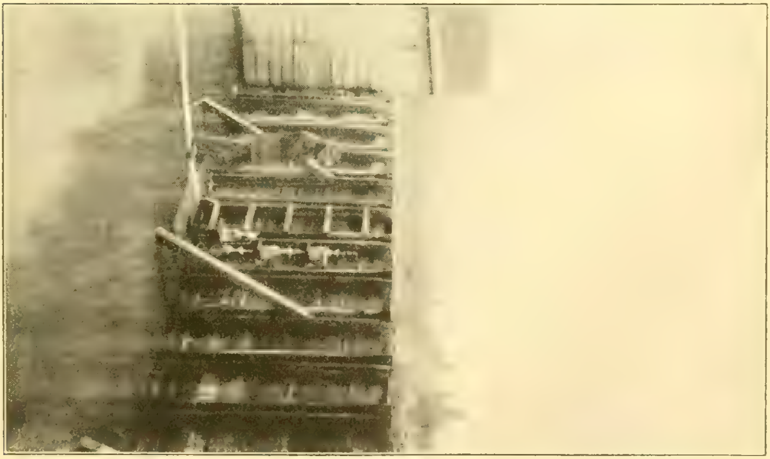


Fig. 19.—Taking Flume Samples.

Silver nitrate was used as the reagent to detect the presence of the sodium chloride. A stock solution was made by dissolving 15 grammes of chemically pure silver nitrate in a liter of distilled water. This solution was kept in a dark-colored bottle in a dark closet in order to prevent action by light. This stock solution was diluted in the ratio of 10 to 1 in making the silver nitrate solution used in titration. This solution was also kept away from the light.

A potassium bichromate solution, having a concentration of 50 grammes per liter, was used to indicate the end point in the reaction of the silver nitrate on the sodium chloride. Only 6 or 7 drops of this solution were used for each titration. The indicator gives a lemon yellow color to the sample when the sodium chloride is in excess, turning to a light orange tint the instant the silver nitrate is in excess.

Hydrochloric acid proved indispensable in cleansing the casseroles after evaporation and titration. However, after cleansing, care was taken to wash away the last traces of the acid with distilled water before using the casserole for another evaporation.

Distilled water was obtained from the Chemical Laboratory of the University of Michigan. It was used in making the silver nitrate solutions, potassium bichromate solution, salt solution, sample dilutions, and in washing and cleansing the apparatus.

METHOD OF EXPERIMENTATION.

In the execution of a single experiment it was generally necessary to obtain data on the following quantities:

Salt Solution Gauging.—

- (1) Dosed flume water sample;
- (2) Normal pond water sample;
- (3) Average salt solution sample;
- (4) Average rate of dosing salt solution:
  - (*a*) Quantity of solution used,
  - (*b*) Duration of experiment;
- (5) Temperature of flume water and salt solution.

Weir Gauging.—

- (1) Average reading of the Fteley and Stearns Gauge;
- (2) Average reading of the Francis Hook-gauge;
- (3) Average reading of the Bazin Hook-gauge;
- (4) Average reading of the piezometer tube.

Subsequent Chemical Analysis.—

(1) Temperatures and volumes of all solutions and samples handled in the laboratory;

(2) Titration, in cubic centimeters of silver nitrate, of all samples.

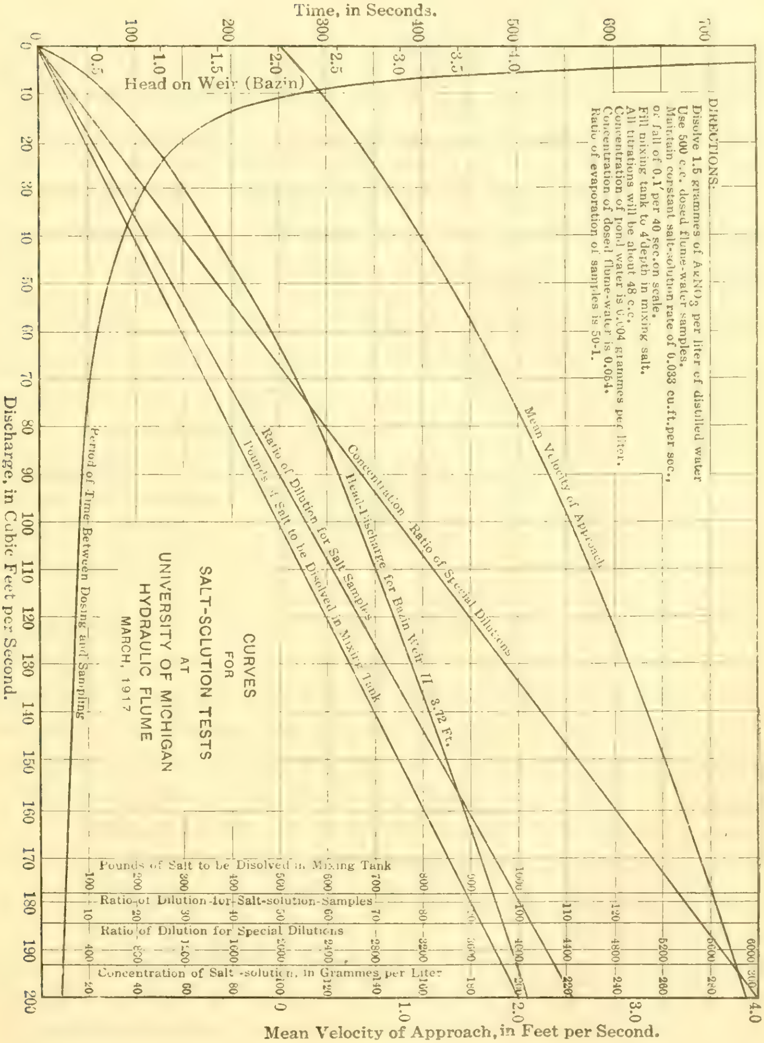
In order to obtain this information, it was necessary to obtain observers to act in the following capacities:

(1) Supervising engineer,
(2) Assistant engineer,
(3) Salt solution gauge observer,
(4) Dosing valve operator,
(5) Recorder for dosing operation,
(6) Pond sampler,
(7) Timer,
(8) Flume water sampler,
(9) Observer at piezometer tube,
(10) Observer at Hook-Gauge No. 1,
(11) Observer at Hook-Gauge No. 2,
(12) Observer at Hook-Gauge No. 3,
(13) Chemist.

Duties of the Observers.—*(1)*.—The duties of the supervising engineer were to outline and organize the work for the experiment, and then critically to observe its progress. By the curve sheet, Fig. 20, he knew the probable weir discharge and flume velocity for any given head on the weir. He advised the assistant engineer as to the number of pounds of salt required for the experiment, and also the specific gravity of the resultant salt solution. He advised the timer as to the probable time which it would take the salt to travel from the point of dosing to the point of sampling. He advised the chemist as to the ratio of dilution for the salt solution sample and the special dilutions.

(2).—The duties of the assistant engineer were to execute the experiment. He attended to the raising or lowering of the flood-gates, filling the mixing and solution tanks, and dissolving the salt. He took observations on the temperature of the flume water and salt solution; checked the timer on the duration of the experiment; and gave assistance to any observer in emergency.

(3).—The duties of the salt solution gauge observer were to note the readings of the piezometer tube, and thus maintain a constant rate



DIRECTIONS.

Disolve 1.5 grammes of $AgNO_3$ per liter of distilled water
Use 500 c.c. dosed flume-water samples.
Maintain constant salt-solution rate of 0.033 cu.ft.per sec., or fall of 0.1′ per 40 sec.on scale.
Fill mixing tank to 4′depth in mixing salt.
All titrations will be about 48 c.c.
Concentration of pond water is 0.004 grammes per liter.
Concentration of dosed flume-water is 0.064.
Ratio of evaporation of samples is 50-1.

CURVES
FOR
SALT-SOLUTION TESTS
AT
UNIVERSITY OF MICHIGAN
HYDRAULIC FLUME
MARCH, 1917

FIG. 20.

of dosing throughout the entire experiment. It had been predetermined that the solution in the tank should fall 0.1 ft. in 40 sec. The observer blew a whistle when the dosing was started. He held a stop-watch in each hand; then, advancing the vernier 0.1 ft. at a time, he started one stop-watch at the same time that he stopped the other, calling off to the recorder and the valve man the number of seconds which it took the solution in the tank to fall 0.1 ft. The valve man proceeded to regulate the control valve so as to obtain and maintain the predetermined rate of flow. After good regulation had been secured, he blew a whistle as the column in the tube passed the next 0.1-ft. mark, giving the recorder the scale reading at this point. He continued to give the recorder the time which it took the salt solution to descend each successive 0.1-ft. division on the scale. After the expiration of 15 min., he ended the experiment by blowing a third whistle as the solution in the tube passed the next 0.1-ft. mark, giving the recorder the final gauge reading. The dosing, however, was continued at the same constant rate until the solution tank was emptied.

(*4*).—The duty of the dosing valve operator was either to close or open the control valve so as to maintain the predetermined salt rate. He also secured two 1-qt. samples of the salt solution continuously during the experiment, taking care to flush both the bottles and lead pipe with the salt solution before sampling.

(*5*).—The duties of the recorder were to record the observations of the initial and final scale readings and the time intervals as given him by the solution gauge observer. He also held a stop-watch from which he obtained the total duration of the experiment, starting the watch at the second whistle and stopping at the third whistle. However, the stop-watch was not relied on entirely, as its reading was always checked by observing the second-hand on an ordinary watch.

(*6*).—The pond sampler secured 1 or 2 gal. of normal pond water from the siphon in the suction pipe of the pump during the progress of the experiment.

(*7*).—The timer occupied a position in the laboratory near the bell push-button, so that he could also see the milli-volt meter indicating the presence of salt. He recorded the time of the first whistle, notifying him that dosing had begun. He then observed the time interval before his milli-voltmeter indicated that salt had arrived in any strength at the sampling section. When the salt arrived at the sampling section in full strength, he rang a long bell. He recorded the time of the second whistle denoting that uniform salt regulation had been attained. Allowing the same period of time after the second whistle as it took the salt to arrive at the sampling section in its prescribed strength after the first whistle, he started the gauge observers reading and the flume sampler sampling by ringing two short bells. Every 20 sec. after this, he rang one short bell, signaling a simultaneous reading of all the weir gauges. He recorded the time of the third whistle indicating that the official dosing had ceased. After a time interval had elapsed, since the third whistle, equal to the time interval which it took for the salt to arrive in any strength at all at the point of sampling after it had left the point of dosing, he finally signaled the flume sampler to cease taking samples and the weir gauge observers to take their final reading. This signal was three long bells. During the entire experiment, he watched the milli-voltmeter, noting any irregularities in its behavior. He checked the difference in time between the second and third whistles with the duration of the experiment obtained by the recorder and the assistant engineer.

(*8*).—The flume water sampler cleaned out his sampling pipes with compressed air before the experiment was started. This blew all scale and sediment away from the small $\frac{3}{64}$-in. orifices. He then set the sampling pet-cocks so that the quantity discharged through them would fill a 1-gal. bottle in about 15 min. At the ringing of the long bell, he flushed out the sampling pipes and washed the sample bottles with the dosed flume water. He accomplished this as rapidly as possible and placed himself in readiness to start taking samples. He started the samples at the ringing of two short bells, finally withdrawing the bottles when three long bells signaled that the experiment had ceased. He immediately corked the sample bottles and carried them to the laboratory. Fig. 19 shows the sampler watching his samples during the progress of an experiment. The photograph was taken during high water, when the tail-water reached the elevation of the floor of the flume. This condition existed only for one week.

(*9*), (*10*), (*11*), *and* (*12*).—All weir gauge observers placed themselves in readiness to read their gauges at the ringing of the single long bell. When two short bells sounded, they took their initial reading, recording the time at which this reading was taken. They then continued to read their gauges every 20 sec., when a single short bell signaled the reading. They took a final reading when the bell rang three successive times, recording this reading, and also the time at which it was taken.

(*13*).—The chemist had three classes of samples to analyze: the dosed flume water, the special dilutions, and the salt solution sample. The method of balanced evaporations required the dosed flume water and special dilutions to be evaporated and the salt solution samples to be diluted, so that final samples of similar volume of all three classes would require approximately the same quantity of silver nitrate solution in titration.

Flume samples were obtained from as many cocks as were submerged during the experiment. Three analyses were performed on each sample, to insure against error and contamination in the laboratory. As a rule, the three analyses agreed very closely and, in almost every instance, two of the three titrations checked within one-tenth of 1 per cent.

Of a flume sample, 500 cu. cm. were first measured in a volumetric flask, noting the temperature of the same. This was then discharged into a separatory funnel for evaporation. This evaporation was conducted over an electric evaporator at a temperature lower than the boiling point. An electric fan blowing the water vapors away from the casserole increased the rate of evaporation about 40 per cent. The entire 500-cu. cm. sample was evaporated until only about 10 cu. cm. remained in the casserole. Care was taken to wash the separatory funnel with distilled water and evaporate this with the rest. Each evaporation required about 7 hours, depending somewhat on the humidity of the atmosphere. The sample was then taken to the burette for titration. The initial reading of the burette was taken after the tube had been filled with silver nitrate solution to within a few cubic centimeters of the top. One drop of potassium bichromate solution was added to the initial sample, and an additional drop was added for every 10 cu. cm. of silver nitrate solution used in the titration of the sample. The silver nitrate solution was added at the rate of about 4 drops per sec., until within a few cubic centimeters of the end point of the reaction. In the meantime, a glass stirring rod was rinsed with distilled water. The final quantity of silver nitrate solution was admitted very slowly, at the rate of a drop in about 2 sec., until a point was reached where the former lemon yellow color of the sample was permanently replaced by a very faint tint of orange. This being the end point sought, the burette reading was recorded. The difference between the initial and final reading, multiplied by 1 000 and divided by the actual volume, in cubic centimeters, discharged by the volumetric flask when the sample was measured for titration, gave the titration per liter of dosed flume water at the laboratory temperature.

The special dilutions were treated in a similar manner. Three dilutions were made for each experiment, in order to check the laboratory processes. The ratio for a given dilution approximated that which was obtained by dividing the weir discharge (computed by formula) by the salt rate, q. In some cases, this ratio could not be attained within several per cent. with the laboratory equipment at hand.

Each dilution was made by taking 10 cu. cm., as measured by a pipette, of the actual salt solution sample obtained during the experiment, and diluting it with the proper quantity of pond water obtained during the same test, until the prescribed ratio of dilution was obtained

In almost every experiment it was necessary to make this dilution in two steps. For example, if a dilution in the ratio of 2 500 to 1 had been desired, it would have been made up as follows:

The contents of two 10-cu. cm. pipettes were discharged into a 500-cu. cm. volumetric flask, which had been washed previously with some of the pond water sample. The flask was then filled to the 500-cu. cm. mark with the pond water sample, and inverted forty times to secure a thorough mixture of the two solutions. The temperatures of both the salt solution and the pond water were recorded. This solution then had a ratio of dilution of approximately 25 to 1. The volume of one 10-cu. cm. pipette filled with this "stock" solution was discharged into a 1 000-cu. cm. of volumetric flask, which had previously been washed with some of the normal pond water sample. The flask was then filled with the normal pond water up to the 1 000-cu. cm. mark and thoroughly shaken to insure a good mixture of the two solutions. The temperature of both the stock solution and the pond sample were recorded. This mixture then had a nominal ratio of dilution of 2 500 to 1. A 500-cu. cm. sample of this dilution was measured and treated in the same manner as the dosed flume water samples.

All precautions and directions advised by Mr. Groat in his paper on "Chemi-Hydrometry" were followed strictly, in order to obtain accurate dilutions.

Dilutions of the salt solution sample with distilled water were made in a similar manner. The ratio of dilution for each experiment was obtained from Fig. 20. The contents of a 10-cu. cm. pipette filled with the dilute solution was discharged directly into a casserole, and titrated in the same manner as the other two classes of samples after evaporation.

From start to finish, the whole experiment progressed as follows:

(1).—The mixing tank was filled with water and the required quantity of salt dissolved in it.

(2).—The flood-gates were adjusted to secure the proper head on the weir.

(3).—The water in the solution tank, in order to keep it soaked, so that its volume would be constant, was discharged. The salt solution was then passed from the mixing tank into the solution tank by gravity.

(4).—The experiment was then ready to begin. The first long whistle announced that the dosing had started.

(5).—A long bell signaled the arrival of the salt at the sampling station. The flume sampler started to flush his pipes and bottles, and the weir gauge readers placed themselves in readiness to read their instruments.

(6).—The second whistle announced the fact that the prescribed uniform rate of dosing had been obtained, and that the experiment had officially begun at the dosing end. The salt solution sample and the pond sample were started at this time.

(7).—Two short bells signaled the flume sampler to take his flume samples, and the hook-gauge readers to take their initial readings.

(8).—Bells every 20 sec. signaled simultaneous readings on all the weir gauges.

(9).—In the meantime, the assistant engineer proceeded to take the temperature of the salt solution and the flume water.

(10).—A third whistle designated the end of the experiment at the dosing station. The valve man discontinued the salt sample.

(11).—Three bells signaled the final gauge readings. The dosed flume water samples were discontinued and carried to the laboratory.

(12).—The chemist then proceeded to analyze the samples.

Record Forms.—Fig. 21 displays the heads of the different forms of records used in recording the data obtained for these experiments.

CALIBRATIONS AND CORRECTIONS.

Stop-Watches.—The four stop-watches used in these tests were placed in the hands of a jeweler 2 months previous to the experiments, with instructions to operate and time them every day. When the experiments were started, all four watches were regulated within 1 sec. of error in 10 hours. However, subsequent regulation was found necessary, the stop-watches being timed each week during the progress of the experiments.

Two types of watches were represented: two continuous-running New England watches, and two Swiss speedway watches with cylinder movement. The New England watches gave much better satisfaction than either of the Swiss watches; but, in no experiment, was the stop-watch relied on absolutely in giving the duration of the test. The dosing recorder and also the timer kept accurate record of the time by observing the second-hand on an ordinary watch. This could be read within a second. In most experiments, the three watches checked each other within a second; in such cases, the stop-watch record was used as the basis for computation.

Variation in Head on the Weir.—The experiments were performed at a period of comparatively high water in the Huron River. In no case did the pond elevation vary more than 0.05 ft. during the progress of the experiment. This insured a practically constant volume of water flowing through the flume.

The hook-gauge records, giving readings taken every 20 sec., show a maximum variation of head on the weir of 0.070 ft. for some high-head experiments. In these instances the water was traveling in the flume at a velocity exceeding 3.3 ft. per sec. With such a high velocity, the waves in the flume were of so great a magnitude that the floating railroad ties were ineffective in decreasing the amplitude of their motions. The variation decreases with a diminishing head on the weir, and, for heads below 3 ft., in no instance exceeds 0.025 ft. These variations are not due to a gradually increasing or diminishing head on the weir, but are either periodic or accidental.

The remarkable agreement between the mean readings for all three hook-gauges and the piezometer tube proves that "variation in head" was ineffective in producing error.

University of Michigan—Experimental Flume.
HOOK-GAUGE RECORD.

Observer____________________ Date ____________________

Hook-Gauge Number________________ Correction of Datum__________

EXPERIMENT NUMBER.	TIME: Beg. and End	READING.	MEAN READING	HEAD ON WEIR

University of Michigan—Experimental Flume.
SOLUTION-TANK RECORD.

Observer____________________________ Date ____________________

EXPERIMENT NUMBER.	TIME: Beg. and End	SECONDS to Fall 0.1'	DURATION. (Sec.)	GAUGE READING.	DIFFERENCE.	VOLUME Cu. Ft.	RATE Cfs.

SPECIAL-DILUTION ANALYSIS.

EXPERIMENT NO.	STOCK DILUTION.							SAMPLE DILUTION.						ANALYSIS.			
	NOMINAL RATIO.	FLASK.		PIPETTE.		TEMP. SALT SOLUTION	TEMP. POND SAMPLE	NO. DILUTION	NOMINAL RATIO	FLASK NO.	PIPETTE NO.	TEMP. STOCK SOLUTION	TEMP. POND WATER	EVAP. COIL NO.	FLASK NO.	TEMP. OF SAMPLE	TITRATION OF $AgNO_3$
		No. of Vol. Used	NUMBER	No. of Vol's Used	NUMBER												

FLUME-WATER ANALYSIS.

DATE.	EXPER. NO.	SAMPLE NO.	EVAP. COIL NO.	FLASK NO.	TEMP. OF SAMPLE.	TITRATION.	MEAN TITRATION PER SAMPLE.	MEAN TITRATION FOR EXPER.

SALT-SOLUTION ANALYSIS.

DATE.	EXP. NO.	NOMINAL RATIO.	FLASK.		PIPETTE.		TEMP. SALT.	TEMP. H_2O	TEMP. STOCK.	PIPETTE NO.	TITRATION.
			VOL'S USED.	NO.	VOL'S USED.	NO.					

RECORD FORMS

FIG 21.

Determination of the Width of the Weir Crest.—Table 1 gives the results of measurements of the width between the sides of the flume for different elevations above the weir crest. The value, for the width of crest, used in the computations, is tabulated in the last column. From top to bottom, these values do not differ more than 0.06 of 1 per cent.

TABLE 1.—Width of Weir Crest.

Height above weir, in feet.	Width of flume, in feet.	Width of weir crest, in feet.
0.00	6.560	6.560
0.25	6.556	6.558
0.50	6.564	6.560
0.75	6.560	6.560
1.00	6.548	6.558
1.25	6.561	6.558
1.50	6.559	6.558
1.75	6.558	6.558
2.00	6.555	6.558
2.25	6.548	6.557
2.50	6.555	6.557
2.75	6.555	6.557
3.00	6.550	6.556
3.25	6.550	6.556
3.50	6.553	6.556
3.75	6.560	6.556
4.00	6.556	6.556

Determination of the Elevation of the Weir Crest Relative to the Gauges.—In order to determine the elevation of the weir crest relative to the weir gauges, the water in the flume was lowered a fraction of an inch below the crest of the weir. A hook-gauge was then placed inside the flume, 1 ft. from the weir. By using a level, the reading of this hook-gauge when the point of the hook was at the elevation of the weir crest was ascertained and recorded. This was tested and checked for several points along the crest. The hook was then lowered to the water level, and simultaneous readings were made on this hook-gauge and those in the gauge shelter. A relation was thus established between the gauges and the weir. Two such tests were made by different observers, the results checking within 0.0001 ft. Actual levels run between the weir and the gauges checked the foregoing results within 0.001 ft. The elevation of Gauge No. 4 was established by levels run between Gauges Nos. 2 and 3. Readings from this gauge can be relied on within 0.001 ft.

Uniformity of the Mixture of the Salt Solution with Normal Water.—Table 2 shows how thoroughly the salt solution became mixed with the pond water as it passed through the flume. The distribution of

TABLE 2.—TITRATION, IN CUBIC CENTIMETERS, OF $Ag\,NO_3$ SOLUTION REQUIRED TO NEUTRALIZE THE SALINE CONTENT OF 500-CU. CM. SAMPLES OF THE DOSED FLUME WATER.

Experiment No.	Head on weir.	SAMPLE COCK NUMBER: 1.	2.	3.	4.	Mean.
1	0.393	58.65	58.15	......	......	58.40
2	0.486	49.84	49.45	......	......	49.65
3	0.680	49.41	49.75	......	......	49.58
4	0.991	43.97	43.40	......	......	43.69
5	1.093	51.93	52.00	.....	.....	51.97
6	1.203	48.78	48.75	......	......	48.76
7	1.309	48.73	48.65	48.72	......	48.70
8	1.379	......	55.69	55.71	......	55.70
9	1.569	......	51.28	51.63	......	51.46
10	1.772	51.71	51.24	52.00	......	51.65
11	1.866	......	......	56.17	......	56.17
12	1.964	......	47.55	47.50	......	47.53
13	2.286	52.60	52.81	52.79	......	52.73
14	2.386	51.42	51.11	51.27	......	51.27
15	2.690	50.77	50.75	50.44	......	50.65
16	2.791	54.20	53.30	52.64	......	53.38
17	2.895	46.45	46.47	47.07	......	46.66
18	3.231	50.05	48.97	49.24	......	49.42
19	3.266	52.40	(50.63)	50.63	50.95	51.15
20	3.344	52.69	51.83	51.95	65.86	55.58
21	3.574	51.40	52.99	(52.70)	52.40	52.37
22	3.757	56.90	52.45	51.66	52.43	53.36
23	3.934	48.73	50.77	50.79	51.17	50.39

the mixture depended somewhat on the manner in which the flood-gates were opened. Better distribution of the salt solution could hardly be desired for all experiments up to 3.344 ft. in head. For higher heads, it was found necessary to lower the submerged weir, in order to secure the higher discharges. The resulting mixture was not as good as in the previous experiments, but only in Experiment 20 was it exceptionally bad. The excess of salt in the sample obtained from Cock No. 4 in this experiment is difficult to explain, and tends to make it less reliable by far than the others.

Calibration of the Solution Tank.—The metal calibrator was calibrated gravimetrically at different temperatures.

Starting with an empty solution tank, the contents of the calibrator were emptied into the solution tank from the spillway platform above. The solution tank gauge readings before and after emptying were recorded. The calibrator was then refilled, and the process was repeated successively until the tank was full.

Two calibrations of the solution tank were made with water at different temperatures at two different times during the progress of the experiment. These calibrations checked within 0.1 of 1 per cent

A mean value of 1.374 cu. ft. for each 0.1 ft. of depth was used in all computations.

The solution tank was never left empty for any length of time, water being always maintained in the tank in order to insure constancy of volume. However, care was taken before each experiment to empty completely all the water from the tank and piezometer before admitting the salt solution. The tank was placed under the spillway platform and in this manner was protected at all times from the heat of the sun.

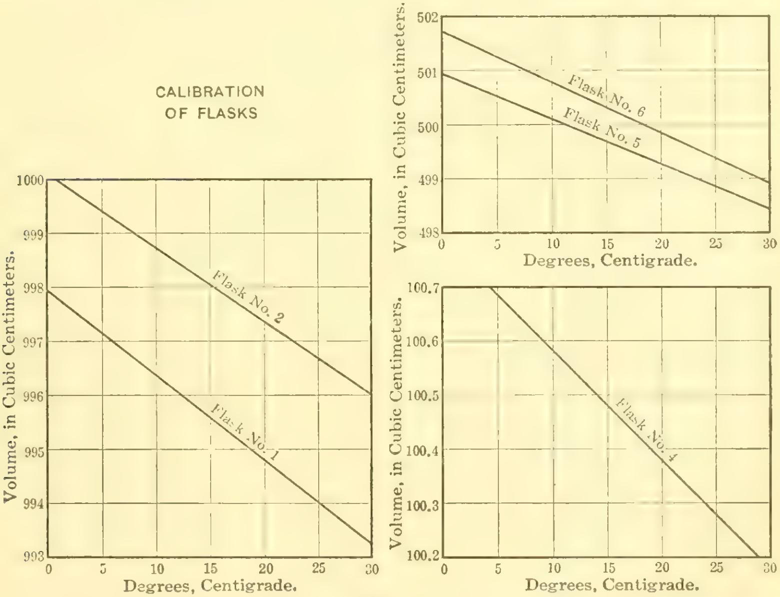


FIG. 22.

Calibration of Flasks and Pipettes.—The flasks and pipettes were carefully calibrated by R. A. Dodge, Teaching Assistant in Hydraulic Engineering, University of Michigan. Most of this work was conducted in the Physical Laboratories of the University, and the remainder on the balances at the flume.

The discharge volume of the pipettes was measured at different temperatures for different concentrations of salt solution. The flasks were calibrated at different temperatures only, using distilled water.

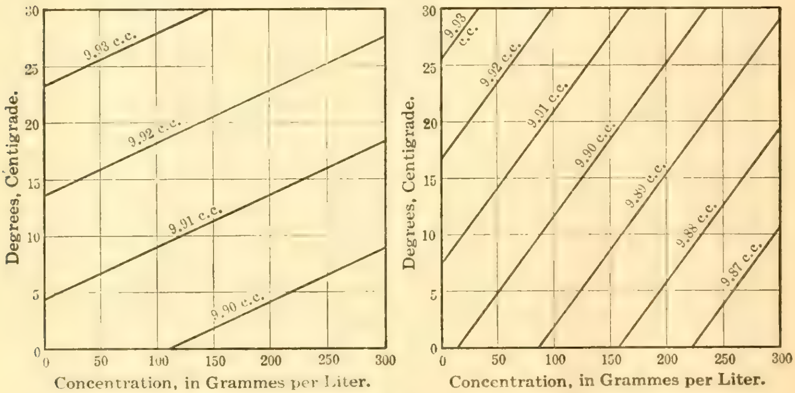
The results of these calibrations are represented graphically by the curves of Figs. 22 and 23. These curves were used in the final computations of the discharge by the salt solution method.

Low-Head Experiments.—For heads on the weir of less than 0.393 ft., with the apparatus at hand, it proved impossible to obtain reliable experiments, using the salt solution method. This was due to the fact that the mean flume velocity was less than 0.2 ft. per sec.; consequently, the mixing of the salt solution was poor, and the sprinkling system was not designed to meet the conditions present for so small a gate-opening.

Computation of Results.

Table 3, Plate I, gives the final computations on the data obtained in these experiments. Each step in the computation is made clear by the explanatory column at the left, designating the mathematical process involved.

CALIBRATION OF PIPETTES.



Pipette No. 1 Pipette No. 2

Fig. 23.

Computations were made in long hand. In general, they were carried out so that a change of one unit in the last significant figure produced a difference of less than 0.03 of 1% in the final result.

The Theiesen, Scheel, and Diesselhorst tables for distilled water, and the Landolt and Börnstein tables for solutions of sodium chloride, were used in all computations. The Williams and Hazen hydraulic tables were used in checking the weir discharge, as computed by the Bazin formula.

The shrinkage coefficient, k, did not depart far enough from unity to change the value of the last significant figure in any of the experiments. It will be noted that it has been tabulated equal to 1.0, although, for some experiments, its actual value was 0.971.

PLATE 1.
PAPERS, AM. SOC. C. E.
JANUARY, 1918.
NAGLER ON
VERIFICATION OF BAZIN
WEIR FORMULA.

TABLE 3.—DATA AND COMPUTATIONS.

Line.			Formula.	Unit.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1....	DATE OF EXPERIMENT, 1917.				April 28.	April 28.	April 27.	April 21.	April 21.	April 20.	April 20.	March 27.	March 27.	March 26.	March 26.	March 24.	March 29.	March 29.	March 30.	March 31.	April 3.	April 4.	May 2.	April 4.	April 5.	April 6.	April 7.
TEMPERATURES.																											
2....	Temperature	Salt solution in tank		°C	8.0	7.0	8.0	11.9	10.5	13.0	13.5	4.0	4.0	7.0	7.9	4.0	8.0	8.0	8.0	8.0	4.0	4.0	6.5	6.0	3.6	2.5	3.0
3....		Salt solution when pipetted for sample		°C	18.5	18.3	27.2	18.8	12.2	12.2	10.5	8.2	12.5	8.8	15.7	14.5	11.8	12.2	14.9	13.2	20.5	12.5	23.0	10.7	17.5	15.5	12.2
4....		Salt solution when pipetted for special dilutions		°C	23.1	24.5	15.0	12.5	21.5	16.5	19.5	22.5	16.5	8.5	17.0	12.1	18.1	12.5	15.0	15.2	11.6	7.7	20.5	9.8	18.0	11.5	17.8
5....		Distilled water when mixed with salt solution		°C	20.1	19.5	24.5	15.9	15.2	12.5	11.5	15.8	12.0	15.0	20.0	20.0	14.7	14.8	14.8	12.2	15.6	18.0	22.0	11.3	14.4	17.5	15.0
6....		Normal flume water when mixed with salt solution		°C	21.8	21.5	16.0	12.2	20.4	14.0	16.7	12.4	14.0	5.0	14.7	11.0	17.8	7.9	15.0	13.0	11.6	6.8	29.5	10.0	16.5	10.7	18.4
7....		Salt solution dilution when pipetted for titration		°C	20.1	19.5	24.5	15.9	15.2	12.5	11.5	15.8	12.0	15.0	20.0	20.0	14.7	14.8	12.0	12.2	15.6	11.5	25.0	12.8	17.0	17.5	15.0
8....		Stock dilution when pipetted for further dilution		°C	......	......	......	14.8	21.0	14.0	18.3	0.7	10.3	13.0	11.0	12.0	16.2	11.5	15.0	13.0	10.2	8.3	30.5	13.0	16.5	11.0	18.4
9....		Pond water used in diluting stock solution		°C	......	......	......	18.6	20.4	14.0	17.4	2.5	10.6	5.0	14.7	11.0	16.2	10.5	15.0	13.0	10.2	7.0	29.5	10.8	16.5	10.7	18.4
10....	Average temperature of special dilution samples			°C	26.5	22.4	16.0	13.6	21.0	15.8	16.9	2.5	10.6	7.0	9.0	11.0	16.2	10.5	15.0	13.0	10.2	8.2	23.3	12.8	17.0	9.4	18.4
11....	Average temperature of dosed flume-water samples			°C	16.9	20.3	20.5	12.2	16.0	11.8	12.5	11.5	13.7	10.8	11.7	10.4	12.2	6.0	18.4	11.5	11.0	11.0	27.2	14.9	14.0	10.5	12.4
12....	Temperature of flume water during the test			°C	8.0	8.0	9.0	11.2	11.2	13.0	13.0	5.0	5.0	7.0	7.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	8.5	6.0	7.0	5.0	4.5
SALT SOLUTION ANALYSIS.																											
13....	Pipette used for salt solution sample in Line 3				1	1	1	1	1	1	1	3	3	3	3	3	3	3	1	1	1	1	1	1	1	1	1
14....	Number of volumes discharged by pipette in Line 13				14	11	7	7	7	6	6	5	4	5	3	3	5	1	1	1	3	2	2	3	1	1	1
15....	Total volume of salt solution pipetted at temperature of Line 3			c.c.	138.986	109.164	69.528	69.433	69.419	59.490	59.454	49.515	39.624	49.505	29.727	29.712	49.490	9.898	9.913	9.912	29.757	19.816	19.840	29.731	9.918	9.909	9.905
16....	Flasks used in measuring the distilled water dilution				6	6	5	2	2	1	1	3	3	3, 6	3	3	2	6	6	6, 4	2	2, 6	2, 6	2, 6	2	2	2
17....	Volume of flasks in Line 16 at temperature of Line 5			c.c.	499.9	499.9	499.4	998.0	998.3	999.0	996.1	999.8	1 000.6	1 500.8	999.0	999.0	1 996.8	500.3	500.3	601.1	1 995.4	1 499.1	1 496.8	2 499.9	998.2	997.7	998.1
18....	Dilute salt solution discharged by pipette at temperature of Line 7			c.c.	9.923	9.923	9.929	9.919	9.916	9.915	9.914	9.923	9.914	9.918	9.923	9.923	9.924	9.918	9.915	9.915	9.919	9.913	9.930	9.915	9.921	9.921	9.918
19....	Titration per pipette of dilute salt solution			c.c.	49.83	43.93	45.50	39.63	47.65	44.58	50.00	49.72	47.76	47.20	44.40	45.70	53.61	44.30	53.34	47.03	43.20	47.48	52.06	46.10	45.08	47.47	50.21
20....	Titration per liter of dilute salt solution at laboratory temperature		1 000 × Line 19 ÷ Line 18	c.c.	5 022	4 427	4 583	3 995	4 805	4 496	5 043	5 011	4 817	4 754	4 474	4 606	5 402	4 466	5 379	4 743	4 355	4 783	5 243	4 649	4 544	4 785	5 062
21....	Ratio of dilution of salt sample		Line 17 ÷ Line 15		3.599	4.579	7.182	14.37	14.38	16.74	16.74	20.19	25.25	30.31	33.61	33.62	40.35	50.54	50.47	60.63	67.05	75.65	75.44	84.08	100.69	100.68	100.76
22....	Titration per liter of salt solution at temperature of Line 3		Line 20 × Line 21	c.c.	18 070	20 270	32 920	57 410	69 100	75 260	84 420	101 170	121 630	144 110	150 370	154 850	217 970	225 710	271 480	287 570	292 000	361 830	395 530	390 890	457 540	481 750	510 050
23....	Concentration of salt solution at temperature of Line 3			g L	9.32	10.46	16.99	29.63	35.66	38.83	43.56	52.20	62.76	74.36	77.59	79.90	112.47	116.47	140.08	148.39	150.67	186.70	204.09	201.70	236.09	248.58	263.19
24....	Approximate percentage of salt solution at temperature of Line 3			%	1.0	1.0	1.6	3.0	3.5	4.0	4.0	5.0	6.0	7.0	7.5	7.5	10.5	11.0	12.5	13.5	13.5	16.5	18.0	18.0	20.5	22.0	22.6
25....	Density of salt solution in tank, at temperature of Line 2				1.0073	1.0073	1.0109	1.0217	1.0255	1.0286	1.0285	1.0377	1.0454	1.0529	1.0561	1.0567	1.0798	1.0840	1.0965	1.1063	1.1080	1.1263	1.1373	1.1330	1.1557	1.1715	1.1752
26....	Density of salt solution at temperature in Line 3				1.0057	1.0057	1.0070	1.0211	1.0252	1.0288	1.0292	1.0370	1.0444	1.0519	1.0536	1.0540	1.0758	1.0811	1.0923	1.0997	1.0987	1.1228	1.1300	1.1357	1.1535	1.1655	1.1711
27....	Density of salt solution at temperature in Line 4				1.0047	1.0045	1.0100	1.0214	1.0221	1.0260	1.0270	1.0334	1.0410	1.0520	1.0535	1.0551	1.0753	1.0810	1.0932	1.0990	1.1007	1.1251	1.1264	1.1361	1.1523	1.1675	1.1685
28....	Density of salt solution at temperature in Line 12				1.0072	1.0072	1.0109	1.0217	1.0254	1.0286	1.0286	1.0375	1.0453	1.0523	1.0561	1.0565	1.0795	1.0834	1.0962	1.1029	1.1023	1.1258	1.1366	1.1376	1.1572	1.1703	1.1745
29....	Titration per liter of salt solution at temperature in Line 12		Line 22 × Line 28 ÷ Line 26	c.c.	18 100	20 300	33 050	57 430	69 110	75 250	84 370	101 220	121 730	144 170	150 720	155 240	218 730	226 230	272 450	288 400	293 040	362 810	398 140	391 640	459 690	484 060	511 780
DISCHARGE OF SALT SOLUTION.																											
30....	Tank gauge board reading at beginning of experiment			ft.	0.900	0.800	0.800	0.800	0.700	0.800	0.800	0.700	0.400	0.600	0.700	0.900	0.800	0.800	0.800	0.600	0.500	0.750	0.600	0.700	0.800	1.200	1.000
31....	Tank gauge board reading at end of experiment			ft.	3.200	3.200	3.200	3.200	2.900	3.200	3.200	3.150	2.700	3.000	3.250	3.300	3.150	3.250	3.150	3.000	2.800	2.950	2.900	3.000	3.100	3.500	3.200
32....	Volume of salt solution discharged at temperature of Line 2		(Line 31 — Line 30) 13.74	cu ft	31.602	32.976	32.976	32.976	30.228	32.976	32.976	33.663	31.602	32.976	35.037	32.976	32.290	33.663	32.290	32.976	31.602	30.228	31.602	31.602	31.602	31.602	30.228
33....	Duration of experiment			sec.	926.0	974.0	946.7	951.0	867.0	953.9	946.4	923.4	922.0	980.0	998.0	985.0	922.8	968.5	925.6	935.2	921.4	869.0	929.0	898.2	917.0	912.8	870.4
34....	Rate of discharge of salt solution at temperature of Line 2		Line 32 ÷ Line 33	c.f.s.	0.03413	0.03386	0.03483	0.03468	0.03487	0.03456	0.03484	0.03646	0.03427	0.03365	0.03511	0.03348	0.03499	0.03476	0.03488	0.03526	0.03429	0.03478	0.03402	0.03518	0.03446	0.03462	0.03474
35....	Rate of discharge of salt solution at temperature of Line 12		Line 34 × Line 25 ÷ Line 28	c.f.s.	0.03413	0.03386	0.03483	0.03468	0.03487	0.03446	0.03484	0.03646	0.03428	0.03365	0.03511	0.03349	0.03500	0.03477	0.03487	0.03528	0.03431	0.03480	0.03404	0.03519	0.03451	0.03465	0.03476
SPECIAL DILUTION ANALYSIS.																											
36....	Volume of salt solution discharged by pipette at temperature of Line 4			c.c.	9.930	9.931	9.920	9.917	9.930	9.921	100.24	9.927	9.929	9.911	9.920	9.914	9.919	9.918	9.914	9.914	9.910	9.904	9.927	9.906	9.918	9.905	9.912
37....	Volume of Line 36 at temperature of Line 12		Line 36 × Line 27 ÷ Line 28	c.c.	9.905	9.904	9.911	9.914	9.897	9.915	100.22	9.886	9.878	9.908	9.894	9.900	9.877	9.889	9.878	9.878	9.880	9.898	9.825	9.891	9.861	9.867	9.852
38....	Numbers on flasks used in making stock dilution				2, 5, 4	2, 6	2, 5	6	5	5	1	6	6	1	5, 4	1, 5	6	6	1, 5	1, 6	1	1, 6	4	1	1	1	1
39....	Number of pipette volumes used				1	1	1	8	7	6	Flask No. 4	5	4	6	4		2	2	5	5	3	4	1	5	2	2	2
40....	Volume of dilution at temperature of Line 5			c.c.	1 597.1	2 494.1	3 494.2	500.6	499.8	499.8	995.3	500.6	500.4	997.2	700.6	1 494.0	500.0	501.0	1 495.9	1 496.4	996.1	1 498.1	400.7	1 992.7	995.3	996.3	995.0
41....	Ratio of densities of dilution at temperature of Line 5 to Line 12				1.0020	1.0020	1.0008	1.0001	1.0014	1.0001	1.0006	1.0005	1.0007	1.0001	1.0008	1.0018	1.0012	1.0001	1.0009	1.0006	1.0004	1.0000	1.0039	1.0002	1.0010	1.0004	1.0014
42....	Volume of dilution at temperature in Line 12		Line 40 ÷ Line 41	c.c.	1 593.9	2 489.1	3 491.4	500.5	499.1	499.7	994.7	500.4	500.1	997.1	700.0	1 491.3	499.4	500.9	1 494.5	1 495.5	995.7	1 498.1	399.16	1 992.3	994.3	995.9	993.6
43....	Ratio of dilution of stock dilution		Line 42 ÷ Line 39 × Line 37		160.93	251.32	351.95	6.3105	7.204	8.400	9.925	10.107	12.656	16.775	17.687	18.829	25.281	25.326	30.259	30.279	33.593	37.838	40.627	40.283	50.401	50.466	50.426
44....	Volume of stock dilution discharged by pipette at temperature of Line 8			c.c.	......	......	......	9.918	9.924	9.918	9.922	9.944	9.913	9.915	9.917	9.913	9.920	9.911	9.916	9.916	9.913	9.911	9.940	9.916	9.920	9.913	9.928
45....	Ratio of densities of stock dilution at temperature of Lines 8 and 12				......	......	......	0.9997	0.9984	0.9999	0.9983	1.0001	0.9997	0.9995	0.9997	0.9985	0.9990	0.9997	0.9991	0.9994	0.9997	0.9999	0.9961	0.9994	0.9990	0.9996	0.9986
46....	Volume of stock dilution pipetted at temperature of Line 12		Line 44 × Line 45	c.c.	......	......	......	9.915	9.908	9.917	9.915	9.945	9.910	9.910	9.914	9.913	9.910	9.911	9.909	9.910	9.910	9.910	9.901	9.910	9.910	9.909	9.918
47....	Volume of flask measuring final dilution at temperature of Line 9			c.c.	......	......	......	998.8	997.8	995.7	995.2	997.6	996.3	997.2	995.9	998.0	993.4	996.3	995.6	996.8	998.3	996.9	993.3	995.0	995.3	996.3	996.0
48....	Volume of Line 47 at temperature of Line 12			c.c.	......	......	......	998.0	995.8	995.6	994.5	997.6	995.0	997.3	994.8	995.6	994.4	993.0	994.5	995.2	996.0	996.9	989.4	995.3	994.3	995.9	993.4
49....	Ratio of dilution of final dilution		Line 48 ÷ Line 46		......	......	......	100.65	100.50	100.39	100.30	100.71	100.40	100.64	100.31	100.43	100.34	100.40	100.36	100.42	100.50	100.59	99.93	100.43	100.33	100.50	100.16
50....	Total ratio of dilution for special dilutions		Line 43 × Line 49		160.92	251.32	351.96	635.15	724.0	843.3	995.6	1 018.0	1 269.9	1 688.3	1 774.2	1 891.0	2 536.6	2 545.0	3 036.8	3 040.6	3 376.1	3 806.1	4 059.9	4 053.7	5 056.7	5 071.8	5 050.7
51....	Value of shrinkage coefficient				1.00	1.00	1.00	1.00	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
52....	Value of ratio of mixture		Line 50 — Line 51		159.92	250.32	350.96	634.15	723.0	842.3	994.6	1 017.0	1 268.9	1 687.3	1 773.2	1 890.0	2 535.6	2 544.0	3 035.8	3 039.6	3 375.1	3 805.1	4 058.9	4 052.7	5 055.7	5 070.8	5 049.7
53....	Flask measuring special dilution for evaporation				5	5	5	5	6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
54....	Volume of flask at temperature of Line 10			c.c.	498.7	499.0	499.6	499.8	500.0	499.6	499.5	500.7	500.1	500.4	500.0	500.9	499.5	500.0	499.8	499.8	500.1	500.25	498.5	499.7	499.5	500.1	499.3
55....	Titration per sample at temperature of Line 10			c.c.	59.80	45.45	51.00	43.57	52.78	49.63	47.56	54.81	52.58	49.37	53.19	47.60	48.35	50.10	49.78	54.49	47.15	51.54	51.89	57.54	49.28	53.45	54.45
56....	Titration per liter at temperature of Line 10		Line 55 × 1 000 ÷ Line 54	c.c.	119.86	91.10	102.08	87.18	105.56	99.34	95.26	109.48	105.14	98.66	106.38	95.20	96.82	100.20	99.60	109.03	94.28	103.03	104.08	115.10	98.56	106.88	109.04
57....	Ratio of densities at temperature of Lines 10 to 12				1.0032	1.0021	1.0008	1.0002	1.0010	1.0003	1.0006	1.0000	1.0003	1.0000	1.0003	1.0001	1.0010	1.0003	1.0007	1.0006	1.0003	1.0001	1.0036	1.0006	1.0010	1.0002	1.0014
58....	Titration per liter at temperature in Line 12		Line 56 × Line 57	c.c.	120.18	91.31	102.16	87.20	105.66	99.37	95.32	109.48	105.17	98.66	106.41	95.24	96.92	100.23	99.67	109.09	94.31	103.04	104.44	115.16	98.66	106.90	109.18
DOSED FLUME WATER ANALYSIS.																											
59....	Flask measuring flume water for evaporation				5	5	5	6	5, 6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
60....	Volume of flask at temperature of Line 11			c.c.	499.3	499.2	499.2	500.6	499.9	500.0	499.9	500.0	499.8	500.0	499.9	500.1	499.9	500.4	499.3	500.0	500.0	500.0	498.7	499.7	499.8	500.0	499.9
61....	Titration per sample at temperature in Line 11			c.c.	58.40	49.65	49.58	43.69	51.97	48.78	48.70	55.70	51.46	51.65	56.17	47.53	52.73	51.27	50.65	53.38	46.66	49.42	51.15	55.58	52.37	53.36	50.39
62....	Titration per liter at temperature in Line 11		Line 61 × 1 000 ÷ Line 60	c.c.	116.94	99.46	99.32	87.26	103.96	97.62	97.42	111.40	102.96	103.30	112.36	95.04	105.48	102.46	101.44	106.76	93.32	98.84	102.56	111.22	104.78	106.72	100.80
63....	Ratio of densities at temperature of Lines 11 to 12				1.0015	1.0016	1.0016	1.0001	1.0006	0.9998	1.0000	1.0005	1.0007	1.0003	1.0001	1.0003	1.0005	1.0000	1.0016	1.0004	1.0003	1.0003	1.0033	1.0007	1.0007	1.0004	1.0005
64....	Titration per liter at temperature in Line 12		Line 62 × Line 63	c.c.	117.09	99.62	99.48	87.27	104.02	97.60	97.42	111.45	103.03	103.33	112.42	95.07	105.53	102.46	101.60	106.80	93.35	98.87	102.89	111.29	104.85	106.76	100.85
COMPUTATION OF DISCHARGE.																											
65....	Line 64 — Line 58		$t_2 - t'_2$	c.c.	− 3.09	+ 8.31	− 2.60	+ 0.07	− 1.64	− 1.87	+ 2.10	+ 1.97	− 2.14	+ 4.67	+ 6.01	− 0.17	+ 8.61	+ 2.23	+ 1.93	− 2.29	− 0.96	− 4.17	− 1.55	− 3.87	+ 6.19	− 0.14	− 8.33
66....	Line 51 × Line 64		$k\,t_2$	c.c.	120.	100	100	90	100	100	100	110	100	100	110	90	100	100	100	110	90	100	100	110	100	110	100
67....	Line 29 — Line 66		$t - k\,t_2$	c.c.	17 980	20 200	32 950	57 340	69 010	75 150	84 270	101 110	121 630	144 070	150 610	155 150	218 630	226 130	272 350	288 290	292 950	362 710	398 040	391 530	459 590	483 950	511 680
68....	Line 65 × Line 50		$R'(t_2 - t'_2)$	c.c.	497.6	2 088.5	915.1	44.46	1 187.4	1 577.0	2 090.8	2 003.7	2 717.8	7 884.4	10 663	321.5	21 840	5 675	5 861.0	6 963	3 241	15 871.4	6 292.8	15 678	31 291.8	710.1	42 072
69....	Line 68 ÷ Line 67		$R'(t_2 - t'_2)/t - k\,t_2$		− 0.0277	+ 0.1034	− 0.0277	+ 0.0008	− 0.0172	− 0.0209	+ 0.0248	+ 0.0198	− 0.0223	+ 0.0547	+ 0.0708	− 0.0021	+ 0.0999	+ 0.0251	+ 0.0215	− 0.0241	− 0.0110	− 0.0438	− 0.0158	− 0.0402	+ 0.0681	− 0.0014	− 0.0822
70....	1 + Line 69		$1 + R'(t_2 - t'_2)/t - k\,t_2$		0.9723	1.1034	0.9723	1.0008	0.9828	0.9791	1.0248	1.0198	0.9777	1.0547	1.0708	0.9979	1.0999	1.0251	1.0215	0.9759	0.9890	0.9562	0.9842	0.9598	1.0681	0.9986	0.9178
71....	Line 52 ÷ Line 70		r		164.5	226.9	360.9	633.6	735.6	860.3	970.3	997.4	1 297.8	1 599.8	1 656.0	1 894.0	2 305.3	2 481.7	2 971.9	3 114.7	3 412.6	3 979.4	4 124.1	4 222.4	4 733.4	5 077.9	5 502.0
72....	Line 35 × Line 71		Q_1	c.f.s.	5.62	7.68	12.57	21.97	25.65	29.64	33.80	36.37	44.49	53.84	58.14	63.43	80.69	86.29	103.63	109.89	117.08	138.48	140.39	148.59	163.35	175.95	191.25
73....	Line 51 × Line 35		δq	c.f.s.	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.04	0.03	0.04	0.03	0.03	0.04	0.03	0.03	0.03	0.04	0.03	0.03	0.03
74....	Discharge by salt solution method. Line 72 + Line 73		Q_s	c.f.s.	5.65	7.71	12.60	22.00	25.68	29.67	33.83	36.41	44.52	53.87	58.18	63.46	80.73	86.32	103.66	109.93	117.11	138.51	140.42	148.63	163.38	175.98	191.28
WEIR OBSERVATIONS AND COMPUTATIONS.																											
75....	Average head by Gauge No. 3—Bazin gauge		h	ft.	0.393	0.486	0.680	0.991	1.033	1.203	1.309	1.379	1.569	1.772	1.866	1.964	2.236	2.336	2.600	2.791	2.895	3.231	3.208	3.344	3.574	3.757	3.934
76....	Average head by Gauge No. 1—Fteley and Stearns gauge			ft.	0.393	0.486	0.679	0.993	1.030	1.199	1.318	1.382	1.571	1.771	1.865	1.967	......	......	......	......	......	......	......	......	......	......	......
77....	Average head by Gauge No. 2—Francis gauge			ft.	0.393	0.487	0.681	0.991	1.034	1.200	1.311	1.381	1.573	1.773	1.869	1.969	......	......	......	......	......	......	......	......	......	......	......
78....	Average head by piezometer tube			ft.	0.392	0.486	0.681	0.992	1.035	1.203	1.308	1.380	1.568	......	......	......	2.290	2.339	2.695	2.769	2.892	3.236	3.281	3.326	3.585	3.751	......
79....	Weir discharge by Bazin formula		$\left(0.405+\frac{0.00984}{h}\right)\left[1+0.55\frac{h^2}{(p+h)^2}\right]Lh\sqrt{2gh}$	c.f.s.	5.62	7.62	12.53	22.05	25.59	29.61	33.70	36.50	44.56	53.83	58.35	63.22	80.28	85.95	103.93	110.27	116.97	139.29	141.69	147.41	163.99	177.56	191.47
80....	Line 74 — Line 79			c.f.s.	+ 0.03	+ 0.09	+ 0.07	− 0.05	+ 0.09	+ 0.06	+ 0.13	− 0.09	− 0.04	+ 0.04	− 0.17	+ 0.24	+ 0.45	+ 0.37	− 0.27	− 0.34	+ 0.14	− 0.78	− 1.27	+ 1.22	− 0.61	− 1.58	− 0.19
81....	Percentage of difference		(Line 80 ÷ Line 74) 100	%	+ 0.53	+ 1.17	+ 0.55	− 0.23	+ 0.35	+ 0.20	+ 0.38	− 0.25	− 0.09	+ 0.07	− 0.29	+ 0.38	+ 0.56	+ 0.43	− 0.26	− 0.31	+ 0.12	− 0.56	− 0.90	+ 0.82	− 0.37	− 0.90	− 0.10

PROBABLE ERROR IN THE MEASUREMENT OF THE DISCHARGE BY THE SALT SOLUTION GAUGINGS.

In every process of calibration, observation, and experimentation, it was sought to eliminate errors greater than 0.1 of 1 per cent. The reliability of the result for any experiment, therefore, is probably best indicated by the excellency of the distribution of the salt content of the differently dosed flume-water samples. This has been discussed, and is exhibited in Table 2.

There is no doubt that some experiments give the correct discharge within 0.1 of 1 per cent. In general, it might be said that the maximum variation from the true discharge is less than 0.6 of 1% for every experiment except No. 20. This may even be claimed for the experiments for which some of the samples are missing, due to the good distribution of the saline content for these discharges. The distribution of the salt in Experiment No. 20 is so bad that the resultant discharge can hardly be relied on within 2 per cent.

The arithmetical mean of the quantities of silver nitrate solution required to titrate the different samples was used as the value of the silver nitrate titration for the entire section. With the excellent salt and velocity distribution in most experiments, this introduced only a negligible error. In fact, due to the equal spacing of the sampling pipe perforations, the arithmetical mean was automatically taken in a horizontal direction; hence, it is doubtful whether the refinement of weighting the samples in a vertical direction is warranted.

Greater accuracy in the chemical gauging could have been attained, had it not been necessary to resort to the evaporation of the samples in making the chlorine analysis. However, the use of the direct method of analysis was prohibitive, for financial reasons, as it would have necessitated putting in a dosing apparatus of larger capacity and also the purchase of a much greater quantity of salt.

The silver nitrate solution used in the titration was as weak as it could be made and still produce accurate results; hence, further weakening of this reagent, in order to reduce the quantity of salt required in a "dosed water sample", was prohibitive. Although it is true that the experiments on the very lowest heads could have been performed with a saturated solution of salt in the existing apparatus, dosing at such a rate that the samples of dosed flume water would

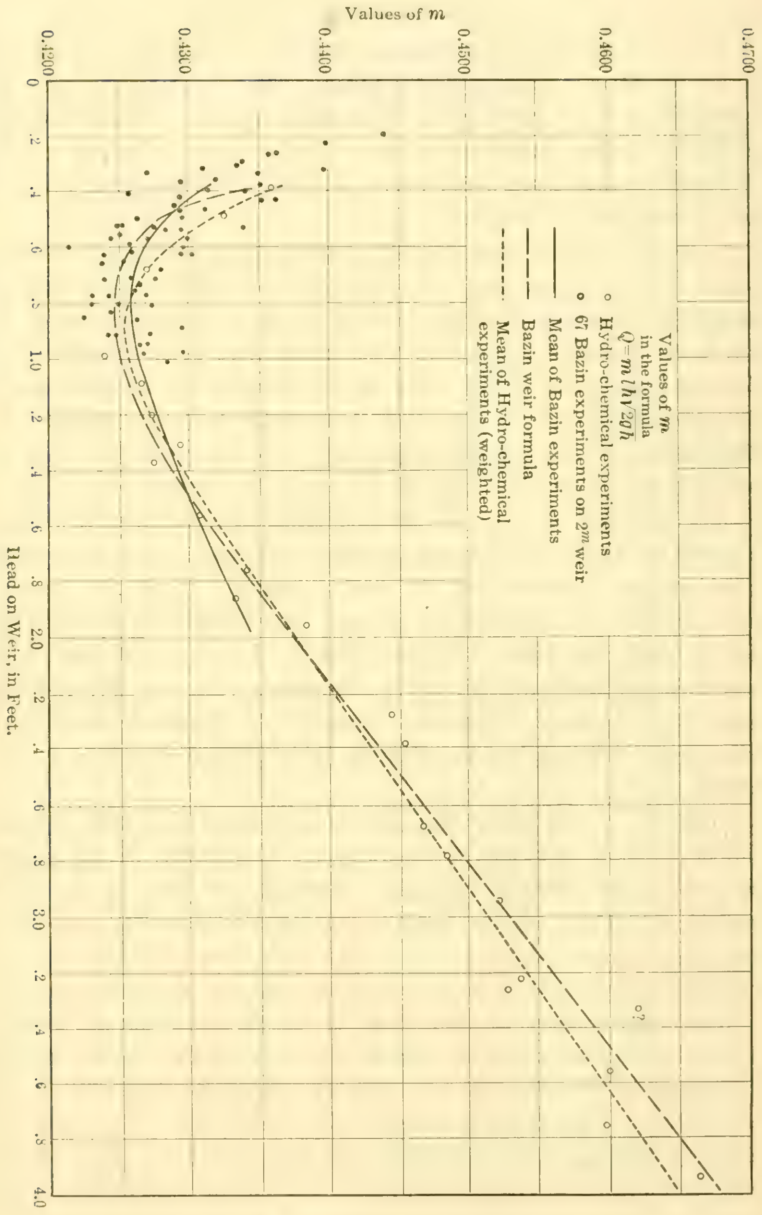

Values of m
0.4200
0.4300
0.4400
0.4500
0.4600
0.4700
Values of m
in the formula
$Q = m\,l\,h\sqrt{2gh}$
○ Hydro-chemical experiments
● 67 Bazin experiments on 2^m weir
Mean of Bazin experiments
Bazin weir formula
Mean of Hydro-chemical
experiments (weighted)
0
.2
.4
.6
.8
1.0
.2
.4
.6
.8
2.0
.2
.4
.6
.8
3.0
.2
.4
.6
.8
4.0
?
Head on Weir, in Feet.

FIG. 24.

require no evaporation before analysis, this could hardly be done for heads in excess of 0.4 ft. on the weir.

The ratio of evaporation used was about 50 to 1; that of dilution was about 6 000 to 1. Direct analysis of the dosed sample, therefore, would require a dilution ratio of approximately 120 to 1, with the same concentration of salt solution for each experiment as was used in these tests. Had the solution tank been of fifty times the capacity of the existing tank, the experiment on the highest head (4 ft. on the weir) could have been executed so as to necessitate no evaporation of the dosed flume water samples; but it would have required the solution of at least 20 tons of salt for the single experiment. This would be about three times as much salt as was actually used in performing the entire set of experiments. As has been previously mentioned, 50 bbl. of salt were used in these tests, costing $1.43 per bbl. Direct analysis would have required 50 × 50 = 2 500 bbl., the cost of which is sufficient reason for resorting to evaporation at the sacrifice of a small degree of accuracy.

Conclusions.

Fig. 24 presents a graphical comparison of these experiments with those of Bazin on a similar weir, the Bazin experimental curve, and the Bazin formula. The weighted mean resulting curve of these experiments is shown by the dotted line. From this comparison, the following conclusions are evident:

(*1*).—For heads of less than 2 ft., the discharges, as given by the salt solution gaugings, are higher than those computed by the Bazin weir formula.

(*2*).—For heads greater than 2 ft., the Bazin formula gives discharges which are greater than those obtained in this set of experiments. This attains a maximum difference of 0.6 of 1% at a head of 4 ft. This fact is proved beyond doubt. In the future, engineers should make this correction in computations on high heads by the Bazin formula.

(*3*).—The salt solution experiments which lie within the range of the Bazin experiments, coincide with the Bazin formula and experimental curve more closely than the Bazin experiments themselves. The 67 experiments performed by Bazin on a weir 2 m. wide and 3.72 ft. high are shown by the small dots on Fig. 24.

(*4*).—The results of the high-head experiments fit the Bazin formula more closely than they would fit the probable extension of the Bazin experimental curve.

(*5*).—In claiming that the Bazin formula gives actual discharge within 1%, within the range of his experiments, this formula is all that its author maintains. There is, however, further merit for the Bazin formula, in that this statement proves to be valid for heads as high as 4 ft., on a weir 3.72 ft. high. The Bazin weir formula is thus extended 100% beyond its original legitimate field of application.

(*6*).—Table 3, Plate I, reveals the fact that simultaneous gauge readings on similar gauges, with similar taps, but applied at different points above the weir, do not differ by more than 0.005 ft. in extreme cases. In some experiments the readings even coincide, and, on the whole, there is no evidence of a tendency toward a definite positive or negative difference one from the other. Such differences as were actually observed might be attributed to accidental error and to the personal error of the different observers. Certainly the fact that the conducting pipe and tapping hole were 2 in. in diameter eliminated all error as to the nature of the tap.

The points at which these gauges tapped the flume duplicated the experimental points of observation used by Bazin, Fteley and Stearns, and Francis. Hence, these experiments seem to indicate that the discrepancies between the Bazin, Francis, and Fteley and Stearns formulas cannot be accounted for by the different points of observation used in their experiments. If the difference is due to the method of tapping, it must be accounted for in the nature of the tap rather than its location.

(*7*).—Finally, Table 4 presents a comparison between the results of these experiments and the following existing weir formulas:

Bazin, $Q = \left(0.405 + \frac{0.00984}{H}\right)\left[1 + 0.55\,\frac{h^2}{(p+h)^2}\right] L\,H\,\sqrt{2\,g\,H}$.

Fteley and Stearns, $Q = 3.31\ L\ H^{\frac{3}{2}} + 0.007\,L;\ H = h + 1.5\,\frac{v^2}{2\,g}$.

Francis, $Q = 3.33\,L\left[(D + h)^{\frac{3}{2}} - h^{\frac{3}{2}}\right]$.

H. W. King, $Q = 3.34\left(1 + 0.56\,\frac{H^2}{(p + H)^2}\right) L\,H^{1.47}$.

TABLE 4.—DISCHARGE PER FOOT OF WEIR CREST.

Head on weir.	CHEMICAL.	BAZIN.		BAZIN.		FTELEY AND STEARNS.		FRANCIS.		KING.	
	Experiment, in cubic feet per second.	Experiment, in cubic feet per second.	Percentage of error.	Formula, in cubic feet per second	Percentage of error.	Formula, in cubic feet per second.	Percentage of error.	Formula, in cubic feet per second.	Percentage of error.	Formula, in cubic feet per second.	Percentage of error.
0.40	0.884	0.874	1.13	0.876	0.90	0.848	4.07	0.845	4.41	0.873	1.26
0.60	1.599	1.591	0.50	1.588	9.69	1.557	— 2.63	1.559	2.50	1.593	0.38
0.80	2.445	2.444	— 0.04	2.437	0.33	2.407	1.56	2.401	1.80	2.448	+ 0.12
1.00	3.416	3.423	+ 0.21	3.410	— 0.18	3.370	— 1.35	3.367	— 1.41	3.424	+ 0.23
1.20	4.506	4.511	- 0.11	4.499	— 0.16	4.467	- 0.87	4.442	— 1.42	4.512	0.13
1.40	5.709	5.706	0.05	5.699	— 0.18	5.661	— 0.86	5.618	— 1.59	5.705	0.07
1.70	7.709	.....	....	9.698	— 0.16	7.650	0.77	7.568	— 1.83	7.682	0.35
2.00	9.928	.....	....	9.923	- 0.05	9.865	0.63	9.704	2.26	9.884	0.56
3.00	18.806	.....	....	18.881	+ 0.40	18.806	0.00	18.160	3.43	18.707	0.53
4.00	29.833	.....	....	30.006	+ 0.61	30.041	+ 0.36	28.416	4.75	29.843	0.03

The columns of Table 4 denoting the percentage of difference between these hydro-chemical gaugings and the other formulas, lead to the following conclusions:

(1).—The agreement with the Bazin experimental curve is remarkably good, except for the low heads.

(2).—The Bazin formula approximates these experiments within 1% for all discharges listed.

(3).—The Fteley and Stearns formula gives good results for the highest heads, but gives discharges too small for heads of less than 1 ft.

(4).—The Francis formula does not agree with these experiments. The discharges vary from 1.4 to 4.75%, and are lower than the hydro-chemical experiments, for both low and high heads on the weir.

(5).—The King weir formula approximates these experiments very closely for nearly all heads; in fact, it seems to fit the data better than any of the existing formulas, except for a divergence of 1¼% at the lowest head.

ACKNOWLEDGMENTS.

The writer is indebted to H. W. King, M. Am. Soc. C. E., Professor of Hydraulic Engineering, University of Michigan, for his assistance and co-operation in making these experiments possible. His interest in the experiments was a continual inspiration, and his suggestions were responsible for many improvements in the manner of conducting them. The writer also wishes to express his appreciation for the invaluable services of R. A. Dodge, Teaching Assistant in Hydraulic Engineering, University of Michigan. The paper by Mr. Groat on "Chemi-Hydrometry" was a constant source of reference in the execution of these experiments. Having used the methods described in this paper very freely, the writer wishes to acknowledge his indebtedness to Mr. Groat. For assistance in the operation of the experiments, the writer wishes to thank Mr. C. O. Wisler, Instructor in Civil Engineering, University of Michigan, and the following senior and graduate civil engineering students at that University in 1917: Messrs. O. B. Apeseche, C. E. Gill, E. R. MacLaughlin, S. P. Davis, T. G. Bedford, G. A. Covarrubias, J. B. Jewell, H. J. McFarlan, E. Gusman, T. B. Dimmick, A. H. Cohn, A. B. Pastor, J. W. Van Brunt, C. E. Wells, M. F. Wagnitz, J. B. Franks, G. A. Pomeroy, and A. Marino.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

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PROGRESS REPORT OF THE SPECIAL COMMITTEE TO REPORT ON STRESSES IN RAILROAD TRACK*

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NOVEMBER 3D, 1917

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* To be presented to the Annual Meeting, January 16th, 1918

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To the American Society of Civil Engineers:

The Special Committee to Report on Stresses in Railroad Track herewith presents a progress report.

I.—Introduction.

1.—Preliminary.—The Committee was formed by action of the Board of Direction on November 12th, 1913. A similar committee, the Special Committee on Stresses in Track, was created by the Board of Direction of the American Railway Engineering Association on November 20th, 1913. In each case, authority was given to co-operate with the Committee of the other Society. The Committee of the American Railway Engineering Association consists of the members of the Special Committee of the American Society of Civil Engineers, sixteen in all, and five other members of the American Railway Engineering Association who do not hold membership in the American Society of Civil Engineers. The Committees of the American Society of Civil Engineers and of the American Railway Engineering Association, under the authorization given, have in effect carried on their work as a single committee. This report is presented simultaneously to the two Societies.

The Board of Direction of the American Society of Civil Engineers made an assignment of funds for the work of the Committee on March 4th, 1914, and a contribution toward the expenses of the tests was received by the American Railway Engineering Association a few days later. Funds having been provided to make a beginning, the initial meeting of the Committee was held in Chicago on March 18th, 1914, when the field of the work and the manner of undertaking it were discussed. At a meeting in Baltimore on June 3d, 1914, the report of a Sub-committee on Organization and Scope of Work was adopted. Mr. W. M. Dawley was made Vice-Chairman of the co-operating committees, and Mr. E. H. Fritch, Secretary of the American Railway Engineering Association, was elected Secretary. Preliminary field work was begun in the summer of 1914, and apparatus and methods of testing were developed as fast as experience could be gained. The work in field, laboratory, and office has since been carried on as actively as the conditions would warrant. Progress reports of the experimental work have been made to the Committee from time to time, and the results of the tests have been discussed at committee meetings and by correspondence. A great deal of time has been consumed in working up the results and in putting the data in form for presentation.

From the beginning the Committee has realized that the problem assigned to it is very complicated, involving many difficulties and uncertainties. It has felt that an adequate report on stresses in railroad track must be based on experimental data derived from extensive tests on standard railroad track. It has also realized that, because of the complexity of the action of track under load and the variability of the conditions which may be found in track and load, adequate experimental work would involve long, painstaking, and repeated tests under many conditions, and also that considerable time would be required for reducing the data thus obtained and interpreting the results. It believed that results of value could be obtained only after prolonged work on the problem. Experience has shown that the anticipated difficulties were not over-estimated. It was found necessary to expend considerable effort and time on the development of instruments for use in the tests and on methods for conducting tests. The problem was studied, and the methods were developed in the light of the information gained during the work. The experimental work undertaken thus far has included the measurement of track depressions, ballast and roadway pressure, and fiber stress in rail, for both static and moving loads, and laboratory tests on the distribution of pressure through ballast.

It is noteworthy that, notwithstanding the importance of track, relatively few experimental data on the general action of the track structure are on record and available as a guide to the Committee in its efforts, or for use in making comparisons with its results. The theoretical or analytical treatments which have been published, principally by European engineers, have most frequently been largely mathematical in character and without experimental verification or connection, and sometimes the assumptions on which the theory was based have been in error. Nevertheless, a number of engineers have made valuable tests on the action of track, notably Dr. P. H. Dudley in the United States, Cuenot in France, and Zimmerman and Ast in Germany and Austria, and these and others have contributed important discussions on several parts of the problem. It is planned to give a bibliography of the literature of the action of track as a structure under load in a later report.* It is apparent, then, that railroad track has not been developed in the manner followed in the development and expansion of most engineering structures and structural parts, where the scientific study of forces and stresses and the use of analysis and experiment have contributed in a marked way to improvements and growth. Instead, the present standards of track have been evolved from previous practice through a process involving extension and trial, and judgment and experience. That track has attained its present state of excellence is a tribute to the sense, insight, and judgment of the many men who have contributed to its growth and development. It is not surprising, then, that the Committee found it necessary to devote considerable effort to studying the fundamental principles of the mechanics of track action, this being done principally through experimental work on structures which may be described as ordinary track in good condition.

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* A comprehensive list of the principal articles on this and related subjects up to 1909, presented by Dr. P. H. Dudley, may be found in *Proceedings*, Am. Ry. Eng. Assoc., Vol. 14 (1913), p. 570.

In the report, the action of track as an elastic structure is first taken up. The part on conduct of tests, which is next in order, includes a description of the apparatus and the method of conducting the tests, a statement of the preparation of test track and procedure of tests, and a discussion of reduction of data and accuracy of instruments. The results of tests are then presented, and various topics related to the action of track are discussed. The information obtained on the action of the tie and on the transmission of pressure through ballast and roadway will be given in a succeeding report.

The Committee is continuing work on the subject assigned to it.

2.—Acknowledgment.—The work of the Committee has been made possible through the contribution of funds by a number of corporations, which have in this way expressed appreciation of the importance of the work and the need for information. Acknowledgment is made to the United States Steel Corporation, the Bethlehem Steel Company, the Lackawanna Steel Company, and the Cambria Steel Company for their financial assistance. The American Society of Civil Engineers has also given support from its treasury.

Railroad companies have co-operated by furnishing facilities for the test work, and thus have contributed largely to the success of the undertaking. The Illinois Central Railroad, A. S. Baldwin, M. Am. Soc. C. E., Chief Engineer, gave the use of its tracks and of its locomotives and crews for the extensive set of tests made north of Champaign, Ill., and credit is due this company for participating so largely in the provision for the tests. The Delaware, Lackawanna and Western Railroad, George J. Ray, M. Am. Soc. C. E., Chief Engineer, gave the use of tracks, locomotives, and crews for the series of tests conducted near Dover, N. J. The Michigan Central Railroad provided the 100-lb. rails for the test track north of Champaign, and the Pennsylvania Railroad supplied the 125-lb. rails used.

Valuable assistance has been rendered by the University of Illinois. By a special arrangement, the Engineering Experiment Station has co-operated by giving the use of laboratory, shop, and office facilities, and through the service of its staff. Mr. H. F. Moore, Professor of Engineering Materials, has devoted considerable time and energy to the design and development of instruments used in the tests, and to the methods of testing. His special qualifications for this work have made his assistance most valuable. Credit should be given Dr. H. M. Westergaard, Instructor in Theoretical and Applied Mechanics, for his helpful work on the mathematical derivation of the equations given in the analysis of the action of track on a continuous elastic support.

To Mr. H. R. Thomas, who, as Assistant Engineer of Tests, has been in immediate charge of the testing operations and of the office work, acknowledgment is due, not only for skill, industry, and insight, but for the zealous spirit of scientific investigation with which the work has been conducted. Mr. R. R. Zipprodt has contributed to the accuracy of the work by his faithful and caretaking reading of records, calculation of results, and assistance in field work. Necessarily, the personnel of the test party has been a changing one, but all those engaged in the work have exhibited care, loyalty, and enthusiasm, which has materially promoted the satisfactory progress of the investigation.

The committee was fortunate in having the advantage of the experience of Dr. P. H. Dudley, a pioneer in testing railroad track. Mr. P. M. LaBach's familiarity with European literature relating to track and track tests has been of service. Since its formation the Committee has lost by resignation of membership J. B. Berry and William McNab, Members, Am. Soc. C. E., whose duties in new positions prevented their giving further attention to the work of the Committee. A further loss in membership occurred through the death of Emil Gerber, M. Am. Soc. C. E.

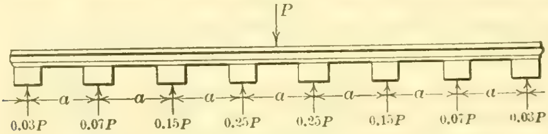
II.—The Action of Track as an Elastic Structure.

3.—*The General Behavior of Track Under Load.*—A proper conception of the fundamentals underlying the action of track under load may be had only by considering the track as an elastic structure under load: The wheel loads are applied on the top of the rails; the rails act as flexible beams which rest on flexible supports (ties); and the ballast and roadway on which the ties rest are themselves yielding or flexible. The action of the various parts of this elastic structure affects the action of other parts. It is evident that the quality of flexibility and elasticity and stiffness of the supporting substructure constitutes an important element in track action, influences very greatly the action of the rail, and affects the stresses developed in the various parts of the track.

Due to the stiffness of the rail and the yielding of its supports, the load from a wheel will be distributed over a number of ties. It is evident that the amount of yielding of the supports affects the values of the moments and stresses developed in the rail. As the distribution of the wheel load among a number of ties produces upward pressures or tie reactions of varying amounts, the determination of these tie reactions is connected with the problem of determining analytically the stresses in the rail. The properties of elasticity and stiffness in the rail, the tie, the ballast, and the roadway enter in a complex manner into the development of the stresses in the track structure, the relative stiffness of the various parts affecting the results in any one part. The spacing of the wheels of locomotives and cars longitudinally along the track also influences the division of the load, as pressures on the various ties, and hence influences the value of the stresses developed in rails, ties, and ballast. The track is flexible, and its action under load is exceedingly complex, especially under the variable conditions found in tie bearings, ballast pressures, and roadway resistances.

Before attempting to give an analytical treatment of the moments and stresses developed in the parts of the track structure, it may be well to discuss in a general way the action of that structure. It is believed that this may be helpful in forming proper conceptions and in showing that certain notions of the manner in which the rail acts are incorrect and misleading.

A number of writers have obtained expressions for the bending moment and stresses in a rail by considering the latter as a simple beam supported on the two adjacent ties, with the wheel load at a point half way between. This assumption gives a positive bending moment under the wheel of $\frac{1}{4}Pa$, where P is the wheel load and a is the distance from center to center of ties. Other writers assume the beam to be fully restrained over the adjacent ties; this makes the positive moment $\frac{1}{8}\,Pa$ and the negative moment $\frac{1}{8}\,Pa$. Among other values which have been put forward are those of $0.18Pa$ for the positive bending moment under the load, and $0.09Pa$ for the negative moment, which is considered to be over the adjoining tie. In all these it is virtually assumed that the load is taken only by the two ties adjacent to the load.

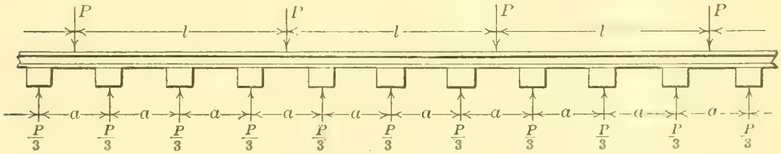


ASSUMED TIE REACTIONS FOR ONE-AXLE LOAD

FIG. 1.

The conditions for a single wheel load may be approximated by taking the upward tie pressures as the loads on the rail and the wheel load as the reaction, and in effect considering the rail cut at the last tie. The wheel load is distributed over a number of ties. The proportional part of the wheel load for each tie reaction depends on the tie spacing, the stiffness of the tie and of the supporting substructure (ballast and roadway), and the stiffness of the rail. Consider that the tie reactions, which approximate the values found in tests, are somewhat as given in Fig. 1. For this assumed distribution of tie reactions, the bending moment under the load will then be $0.63Pa$, if we consider that the rail is not held down in such a way as to give negative reactions and negative resisting moments away from the wheel. It is seen from this illustration that a single load may give a high bending moment in the rail.

If, now, we consider a rail with an indefinitely large number of evenly spaced wheel loads, the tie spacing being, say, not more than one-third of the wheel spacing, it can be shown that, for a given wheel spacing, there is relatively little difference in the tie reactions until the wheel spacing becomes quite large. Assuming for present purposes that the tie reactions are equal, and that the wheels are at points midway between ties (Fig. 2), the positive bending moment under loads three tie spaces apart is found to be about $0.263Pa$, and the negative bending moment $-0.154Pa$; and $0.345Pa$ and $-0.156Pa$, respectively, when the wheel spacing is four tie spaces. Expressing the bending moments in terms of the wheel spacing, l, the values become $0.088\,Pl$ and $-0.051\,Pl$ for $l = 3a$, and $0.086\,Pl$ and $-0.039\,Pl$ for $l = 4a$. It is readily seen from this that, for the conditions assumed, the bending moments—and therefore the stresses in the rail—will be dependent on the wheel spacing, and that this influence will continue until the wheel spacing becomes so great as to approach the conditions of single loads.



SERIES OF LOADS
WITH ASSUMPTION OF EQUAL TIE REACTIONS

FIG. 2.

The foregoing refers only to an indefinitely large number of wheel loads. For a small number the results will be greatly modified. In case two, three, or four wheels are spaced as above, it may be expected that the positive moment developed under the first and last loads will be greater than the foregoing values, and the moment under intermediate wheels somewhat less than at the outer wheels. The amount of this difference will depend on the properties of the track, including the stiffness of the rail. When there are other wheel loads, as truck wheels, not too far away, their effect is to modify the moments produced under the main wheels. On the whole, the problem is very complicated.

It is apparent that, for conditions here considered, changes in the closeness of tie spacing have relatively small effects on the bending moment developed in the rail by a given wheel loading; thus, for a wheel spacing equal to three tie spaces and an indefinitely large number of wheels thus spaced, the positive moment is about $0.088Pl$;

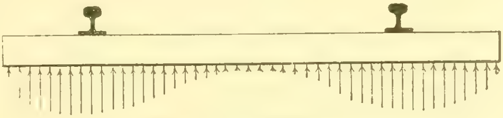
and, if the ties were spaced so closely as to approach conditions of uniform distribution of bearing pressures from wheel to wheel, the positive bending moment would be approximately $0.083Pl$. It is also well to note that, by this method of analysis, the bending moment under the wheel may be expected to be nearly as much for wheels placed over ties as when they are midway between ties. The foregoing discussion is based on an assumption of uniform resistance of the substructure; namely, that the stiffness of the elastic support is the same at each tie. It is evident that the stresses in the rail will be modified by the varying conditions of the tie, ballast, and roadway from point to point along the track.

Another important element in the problem of determining stresses in track is the effect of speed of locomotive and train. On this matter analysis alone can give little real information, and it must be expected that reliance must be placed on experimental data.

The reaction of the tie or its upward pressure on the rail depends on the stiffness or the yieldability of the ballast and roadway, and also on the stiffness of the rail, which, of course, is dependent on its moment of inertia. For good track and for a wheel spacing of not more than three or four tie spaces, the tie reactions for the ties between wheels will not vary greatly from each other. In front of the front wheel and behind the rear wheel of a set of wheels, and also in front of and behind a single wheel, the division of the reactions among various ties will be dependent on the stiffness of the track (rail, tie, ballast, and roadway). The determination of this stiffness is one of the problems connected with the experimental work.

The distribution of the upward pressure of the ballast against a tie along its length may be expected to vary with the tamping and with the ballast and roadway conditions, and also depends on the dimensions of the tie. For usual conditions of good track, it would seem that the upward pressure will continue from the rail to the end of the tie and for at least a similar distance inside the rail. The exact distribution will depend on the amount of bending of the tie and on the permanent depression made in the ballast by the previous applications of load, as well as on the yieldability of the ballast and roadway. It will help in getting a conception of the action of the tie and ballast to consider the tie to be set on a bed of stiff springs; under load, the tie bends and the springs compress in proportion to the load put on them. The stiffness of the springs depends on the nature of the tie bearing and the consolidation of the ballast and other bearing material, and their elastic properties. At the middle point of the tie the springs will generally have little bearing resistance. Fig. 3 gives a general notion of the distribution of the load along a tie. However, it must be expected that changes in the conditions of ballast and roadway--like freezing and thawing—differences in bearing conditions of adjacent ties, and the differences in resistance to repetition of pressure on the ballast along the length of the tie, greatly modify the distribution; and such changes may be expected to increase the bending stresses in the tie.

It is usual to think of the distribution of pressure across the width of the tie as being nearly uniform; that is, to consider the whole width of the tie as equally effective in transmitting pressure from the tie to the ballast. The ballast, however, is composed of non-cohesive particles. As the transmission of pressure in directions other than the vertical is dependent on friction between particles, the vertical pressures at the edge of the tie must be less than the pressures transmitted from the middle of its width, and this difference results in a distribution of pressure far from uniform across the width of the tie. For ties which are spaced not too far apart, there is something of a reaction from the adjoining tie, which may be expected to improve the distribution across the face. On the whole, however, the upward pressure against the tie cannot be uniform across its width.



A DISTRIBUTION OF PRESSURES ALONG A TIE

FIG. 3.

The ballast, as a part of the structure of the track, in addition to other important purposes, such as drainage, serves to transmit the tie pressures and reactions to the roadway, and acts to distribute the pressure more nearly evenly over the surface of the roadway. The laws governing the distribution and transmission of pressure through the ballast must be expected to have an important bearing on the proportioning of the track structure. The formulation of these laws and the determination of constants relating to stiffness or yieldability must await experimental work.

The roadway itself, acting as a support, also serves to transmit pressures and to distribute them to the surface of the earth below. The conditions of the roadway and the materials of which it is made may be expected to affect the action of the track. Little is known about this.

Enough has been stated to show that the problem of the stresses in track is not a simple one, that it involves a large number of elements which have the nature of variables, that these variables enter into the problem in a complex manner, and that it is necessary to have a diversity of experimental data relating to the several variables before attempting to formulate the laws governing the stresses in track.

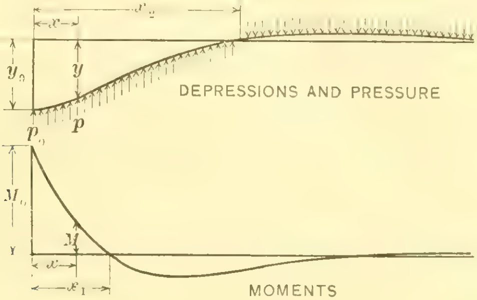
4.—Analysis of Track Action.—An analytical treatment of the action of track under load has a value in the comparison of experimental data. It will be of use in establishing the physical properties of track, and should be an aid in forming proper conceptions of the manner in which track acts under load. It will be found to be a convenience in discussing the effect of rail section, tie spacing, driver and wheel spacing, depth of ballast and its stiffness, and condition of roadway. Such analyses are based on the theory of flexure, and involve complicated mathematical procedure. It may not be expected that an analysis of track action will fit accurately the many variables of track, and, besides, the track varies in its properties from point to point. What is wanted is an analysis that may readily be used and that may easily be applied to combinations of wheel loads, to variations in wheel spacing, and to particular physical conditions of track. Most analytical treatments give results in such complicated form that their application is time-consuming. The simplified forms of analysis may not have a wide range of applicability. Various methods of analysis have been examined, including those given in foreign publications. Much time and considerable effort have been devoted to a study of possible analyses, and a variety of methods of attack have been taken up. As a result, it is concluded that the method of analysis which is based on the assumption of a continuous elastic support under the rail is by far the most convenient, most easily applied, and most comprehensive in its application to the questions involved in the work of the Committee. This analysis lends itself very readily to a discussion of the general problems of track.

The assumption of a continuous support in place of tie supports is not an element of serious inaccuracy for the close tie spacing and large rail sections used on American railroads, especially as the use of values of track stiffness determined from data taken from tests on ordinary track carries into the constants established much of the condition of concentrated tie loads. The results of this analysis are similar in general character to those tried using concentrated tie loads. The method has been found to be more general and to have fewer limitations than the methods based on concentrated tie loads.

The term, modulus of elasticity of rail-support, is introduced as a measure of the vertical stiffness of the rail-support. It may be defined as the pressure per unit of length of each rail required to depress the track one unit. It represents the stiffness and yieldability of tie, ballast, and roadway, but does not involve the stiffness of the rail. As applied to ordinary track, the load on one rail required to depress one tie one unit, divided by the tie spacing, will give the modulus of elasticity of rail-support. As an illustration, consider that a series of wheel loads which depress the track an average of 0.3 in. gives a load equivalent to 10 000 lb. per tie for each rail, and that the tie spacing is 22 in.; the modulus of elasticity of rail-support is then 1 500 lb. per inch of length of rail per inch of depression. The value of the modulus of elasticity of rail-support is so related to tie spacing and tie dimensions, depth of ballast, quality of tie, solidity of roadway, character of tamping and surface, and other conditions of the track and its maintenance, that it will vary considerably according to the quality of the track.

The method of analysis will be developed, first for a single wheel load and then for a combination of wheel loads.

5.—Depressions, Upward Pressures, and Bending Moments in Rail for Track having a Continuous Elastic Support; Single Wheel Load.—Assume that the rail is supported continuously on an elastic support and that the support has a constant modulus of stiffness; that is, that the depression of the track and the resulting upward pressures on the rail are directly proportional to each other. Assume, further, that the track construction is such that negative pressures may be developed. The following nomenclature will be used (see Fig. 4):



DISTRIBUTION OF DEPRESSION,
AND BENDING MOMENT FOR SINGLE-WHEEL LOAD

FIG. 4.

P = wheel load on rail at point which will be used as the origin of abscissas;

E = modulus of elasticity of steel;

I = moment of inertia of section of the rail;

y = depression of rail at any point, x, it being assumed that there is no play or back-lash in the track; downward displacement of rail is negative; however, in the applications to track, the ordinary downward depressions of track will be spoken of as positive;

y_0 = depression of rail at point of wheel load ($x = 0$);

p = upward pressure against rail per unit of length of rail at any given point;

p_0 = upward pressure against rail per unit of length of rail at the given wheel load ($x = 0$);

u = an elastic constant which denotes the pressure per unit of length of each rail necessary to depress the track (rail, tie, ballast, and roadway) one unit; for the system of units ordinarily used, it will be expressed in pounds per inch of length of rail required to depress the track 1 in.; u represents the stiffness of the track, and involves conditions of tie, ballast, and roadway; it is termed the modulus of elasticity of rail-support;

M = bending moment in rail at any point;

M_0 = bending moment in rail at point of wheel load due to single wheel load ($x = 0$);

x_1 = distance from wheel load to point of zero bending moment in rail;

x_2 = distance from wheel load to point of zero upward pressure; it will be shown that x_2 is $3x_1$;

e = base of natural system of logarithms = 2.7183.

The fundamental condition on which the analysis is based is that the track depression at any point and the upward pressure on the rail per unit of length at the same point are directly proportional to each other. In other words, $p = uy$.

It will be recalled that, in the mechanics of beams, the derivatives of the elastic curve (first, second, third, and fourth), in their order, represent or are proportional to (1) the slope of the elastic curve, (2) the bending moment in the beam, (3) the shear, and (4) the intensity of the load. In the case in hand, the fourth derivative (the intensity of the load) has the unique relation of being directly proportional to the original function, given by the equation of the elastic curve or curve of depression of track.

From the fundamental condition, the differential equation of equilibrium* is

$$E\,I\,\frac{d^4\,y}{d\,x^4} = u\,y \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

This differential equation is satisfied by the following equation:

$$y = -\frac{P}{\sqrt[4]{64\,E\,I\,u^3}}\,e^{-x\sqrt[4]{\frac{u}{4\,E\,I}}}\left(\cos. \times \sqrt[4]{\frac{u}{4\,E\,I}} + \sin. \times \sqrt[4]{\frac{u}{4\,EI}}\right) . (2)$$

---

* The method of attack used in this mathematical solution may be found in Föppl's "Technische Mechanik", Vol. III, pp. 254–268, Edition of 1900, where a treatment of various problems concerning beams on continuous elastic supports is given. The method of analysis is here applied directly to the problem of track, and especially to the bending moment in the rail.

The successive derivatives of this expression are:

$$\frac{dy}{dx} = \frac{2P}{\sqrt{16\,E\,I\,u}}\,e^{-x\sqrt[4]{\frac{u}{4EI}}}\sin.\,x\sqrt[4]{\frac{u}{4\,E\,I}} \quad \ldots\ldots\ldots\ldots (3)$$

$$M = E\,I\frac{d^2y}{dx^2} = P\sqrt[4]{\frac{E\,I}{64\,u}}\,e^{-x\sqrt[4]{\frac{u}{4EI}}}\left(\cos.\,x\sqrt[4]{\frac{u}{4\,E\,I}} - \sin.\,x\sqrt[4]{\frac{u}{4\,E\,I}}\right) \quad (4)$$

$$E\,I\frac{d^3y}{dx^3} = -\frac{P}{2}\,e^{-x\sqrt[4]{\frac{u}{4EI}}}\cos.\,x\sqrt[4]{\frac{u}{4\,E\,I}} \quad \ldots\ldots\ldots\ldots (5)$$

The equation for intensity of pressure against the rail is

$$p = -u\,y = P\sqrt[4]{\frac{u}{64\,E\,I}}\,e^{-x\sqrt[4]{\frac{u}{4EI}}}\left(\cos.\,x\sqrt[4]{\frac{u}{4\,E\,I}} + \sin.\,x\sqrt[4]{\frac{u}{4\,E\,I}}\right) \quad \ldots (6)$$

The mathematical derivation of these equations will not be given, but the solution is seen to be correct because, at the same time, two types of conditions are satisfied:

1,—The differential equation is satisfied by Equation (2) for all positive values of x.

2.—All necessary conditions at special points are satisfied as follows:

$$E\,I\frac{d^3y}{dx^3} = \frac{P}{2} \text{ for } x = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (a)$$

$$\frac{dy}{dx} = 0 \text{ for } x = 0 \text{ and } x = \infty \quad \ldots\ldots\ldots\ldots\ldots\ldots (b)$$

$$y = 0 \text{ for } x = \infty \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (c)$$

The following special value of the functions will be useful:

The distance from the wheel load to the point of zero bending moment in the rail ($M = 0$ in Equation (4)) is

$$x_1 = \frac{\pi}{4}\sqrt[4]{\frac{4\,E\,I}{u}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

The value of the maximum bending moment in the rail (which is at the wheel load) ($x = 0$ in Equation (4)) is

$$M_0 = P\sqrt[4]{\frac{E\,I}{64\,u}} = 0.318\,P\,x_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

The value of the maximum track depression (which is at the wheel load) ($x = 0$ in Equation (2)) is

$$y_0 = -\frac{P}{\sqrt[4]{64\,E\,I\,u^3}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

The value of the maximum intensity of upward pressure (which is at the wheel load) ($x = 0$ in Equation (6)) is

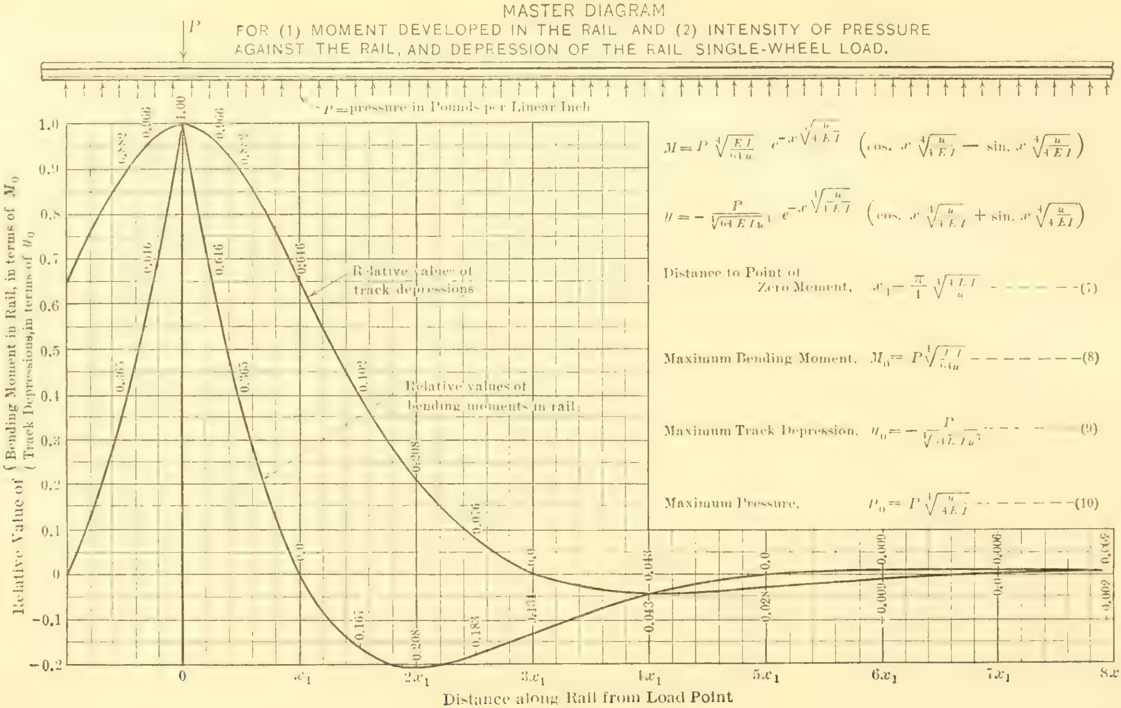
$$p_0 = P \sqrt[4]{\frac{u}{64\,E\,I}} = -\,u\,y_0 \dots\dots\dots\dots\dots\dots (10)$$

The distance from the wheel load to the point of zero upward pressure on the rail ($p = 0$ in Equation (6)) is

$$x_2 = \frac{3\,\pi}{4} \sqrt[4]{\frac{4\,E\,I}{u}} = 3\,x_1 \dots\dots\dots\dots\dots\dots (11)$$

Fig. 5 gives master diagrams for (1) the moment developed in the rail, and (2) the intensity of pressure against the rail and the depression of the rail, as determined from the foregoing equations. The diagrams represent relative values. The bending moment under the wheel load is given as unity, and the values of the bending moment at other points (given as ordinates of the bending moment curve) are expressed in terms of the bending moment at the wheel load. The intensity of upward pressure (represented by the ordinate to the pressure curve) is also expressed in terms of the intensity of pressure at the wheel load as unity. Similarly, the abscissas of the two diagrams (bending moments and pressures) are expressed in terms of the distance from the wheel load to the point of zero bending moment as unity; *i. e.,* as abscissa ratios. For any given track conditions, the value of the maximum bending moment, M_0, may be computed by Equation (8) and the distance, x_1, to the point of zero bending moment by Equation (7). To get the bending moment at any given point, find the ratio of x for the given point to x_1 and take the ordinate from the diagram by using this ratio as the abscissa. The bending moment in the rail at the given point will then be found by multiplying the value of the maximum moment, M_0 (already computed), by the ordinate found from the diagram. Similarly, the value of the intensity of pressure at a given point may be determined by multiplying the intensity of pressure under the wheel load by the ordinate for pressure at a given point obtained from the diagram.

As an illustration, consider a 100-lb. rail section ($I = 44$) and that, for the track conditions, $u = 1\,500$ lb. per inch of length of rail per inch of depression. x_1 is found to be 34 in. For a point 66 in. from the wheel load, the abscissa ratio is then $\frac{x}{x_1} = \frac{66}{34} = 1.94$. From the master diagrams (Fig. 5), the bending-moment ratio at the abscissa ratio, 1.94, is $-\,0.20$; that is, the bending moment at 66 in. from the wheel load is 0.20 of that at the wheel load, and is negative. By Equation (8) the maximum moment, M_0, is 10.8 P. The bending moment at a point 66 in. from the



$$M = P\sqrt[4]{\frac{EI}{64u}}\; e^{-x\sqrt[4]{\frac{u}{4EI}}}\left(\cos.\, x\sqrt[4]{\frac{u}{4EI}} - \sin.\, x\sqrt[4]{\frac{u}{4EI}}\right)$$

$$y = -\frac{P}{\sqrt[4]{64EIu^3}}\; e^{-x\sqrt[4]{\frac{u}{4EI}}}\left(\cos.\, x\sqrt[4]{\frac{u}{4EI}} + \sin.\, x\sqrt[4]{\frac{u}{4EI}}\right)$$

Distance to Point of Zero Moment, $x_1 = \frac{\pi}{4}\sqrt[4]{\frac{4EI}{u}}$ - - - - - - (7)

Maximum Bending Moment, $M_0 = P\sqrt[4]{\frac{EI}{64u}}$ - - - - - - - - (8)

Maximum Track Depression, $y_0 = -\frac{P}{\sqrt[4]{64EIu^3}}$ - - - - - - (9)

Maximum Pressure, $P_0 = P\sqrt[4]{\frac{u}{4EI}}$ - - - - - - - (10)

FIG. 5.

wheel load is then the product of M_0 and — 0.20, which is — 0.216P. For the same point ($x = 66$ in.), the relative value of the intensity of pressure is found from the diagram to be 0.22. By Equation (10) the intensity of pressure at the wheel load, p_0, is 0.0115 P. The pressure 66 in. away is then the product of p_0 by 0.22, which is 0.0025 P.

It may be well to call attention to the effect of changes in the various properties of track on the resulting track depressions and bending moments in rail, as indicated by the several equations already given for a single wheel load. From Equation (9) it is seen that y_0, the track depression under the wheel, varies directly as the magnitude of the wheel load, P, and that it varies inversely as the fourth root of the moment of inertia of the rail section and inversely as the three-fourths power of the modulus of elasticity of rail-support. By this formula, doubling the moment of inertia of the rail section will result in a track depression under the wheel 84% as great as that for the lighter rail. Increasing the stiffness of the track support in such way as to double the modulus of elasticity of rail-support will result in a track depression 59% as great as that for the less stiff track. From Equation (8) it is seen that M_0, the bending moment in the rail under the wheel, varies directly as the magnitude of the wheel load, P, and that it varies directly as the fourth root of the moment of inertia of the rail section and inversely as the fourth root of the modulus of elasticity of rail-support. By this formula, doubling the moment of inertia of the rail section will result in a bending moment in the rail under the wheel 1.19 times as great as that for the lighter rail. Increasing the stiffness of the track support in such way as to double the modulus of elasticity of rail-support will result in a bending moment in the rail under the wheel 84% as great as that for the less stiff track. It should be noted that the foregoing applies to results for a single wheel load on a rail; the effect of two or more wheel loads is discussed in the following article.

6.—Combination of Wheel Loads.—To find the effect of a combination of wheel loads on the track depressions and the pressures and the bending moment in the rail, as may occur with a given type of locomotive, the equations and diagrams for a single wheel load may be applied by the use of the principle of superposition; *i. e.*, by considering that, at a given point along the rail, the combined effect of two or more wheel loads is the algebraic sum of the effects of the individual wheel loads. The effect which each wheel produces at any given point may be determined from the master diagrams (Fig. 5), and the cumulative effect of the several loads may then be found by adding the components produced by each wheel load. This method of superposition of components is applicable to bending moments as well as to track depressions and pressures. The method may best be described by an illustrative example.

Take a Mikado locomotive, with the wheel loads and wheel spacings given in Fig. 6, and let the problem be to calculate the bending moments in the rail at various points. In using Fig. 5, take as the abscissa the ratio, $\frac{x}{x_1}$, where x is the distance from the given point to the wheel load the effect of which is to be determined and x_1 is the distance from the wheel to the point of zero bending moment in the case of a single wheel load. The bending moments will be obtained in terms of the maximum bending moment for a single wheel load (Equation (8)).

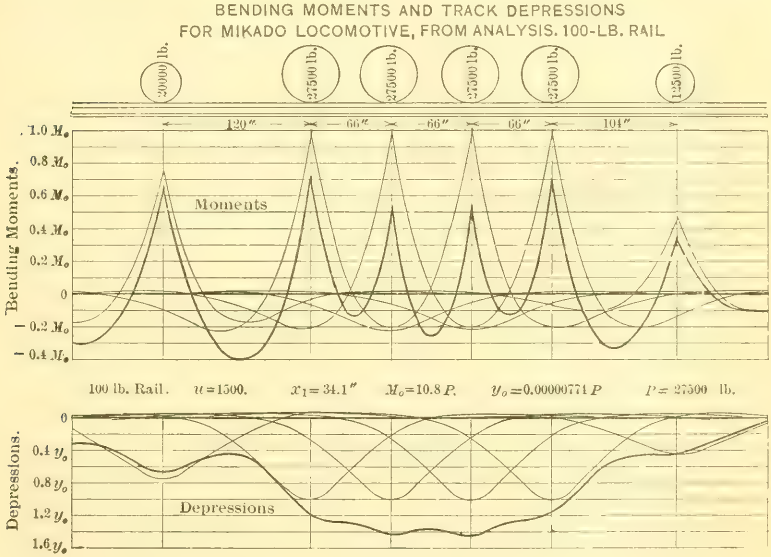

BENDING MOMENTS AND TRACK DEPRESSIONS
FOR MIKADO LOCOMOTIVE, FROM ANALYSIS. 100-LB. RAIL

Fig. 6.

To find the bending moment produced by a wheel load at a section in the rail x distant from the wheel load, take from the moment diagram in Fig. 5 the ordinate (which gives relative values of bending moments) corresponding to the given abscissa ratio, $\frac{x}{x_1}$. The values may best be kept as relative values and considered as effects of the several wheel loads until the components have been summed. The bending moment at the given point may then be found by multiplying the maximum bending moment for a single wheel load (as found from Equation (8)) by the ratio found by the summation of components. Where the wheel loads are unequal, use the ratio of the wheel loads in the calculations; thus, if the effect of the pilot truck wheel on a point at the first driver is to be found, use the ratio $\frac{12\ 500}{27\ 500}$.

Consider that the track conditions are such that the modulus of elasticity of rail-support, u, is 1 500 lb. per inch of length of rail per inch of depression. Consider a 100-lb. rail section, with $I = 44$. The value of the bending moment under a wheel load, where uninfluenced by other wheel loads, becomes, for the constants of the track, from Equation (8), $M_0 = 10.8\ P$. From Equation (7), $x_1 = 34$ in For the distance from the first driver to the pilot truck wheel the abscissa ratio, $\frac{x}{x_1}$, is $\frac{104}{34} = 3.06$. For the distance from the first driver to the second driver the abscissa ratio, $\frac{x}{x_1}$, is $\frac{66}{34}$ 1.94. For the distance from the fourth driver to the trailer the abscissa ratio, $\frac{x}{x_1}$, is $\frac{120}{34} = 3.53$. Take ordinates from Fig. 5 for the several abscissa ratios. The effects of the several wheels are then found, and these components are added algebraically.

Bending Moment at First Driver:

Effect of first driver	+ 1.00
Effect of pilot truck wheel, $\left(\frac{x}{x_1} = 3.06\right)$ — 0.13 $\times \frac{12\ 500}{27\ 500}$	— 0.06
Effect of second driver $\left(\frac{x}{x_1} = 1.94\right)$	— 0.20
Effect of third driver $\left(\frac{x}{x_1} = 3.88\right)$	— 0.05
	+ 0.69

The bending moment at the first driver is then 0.69 of that due to the weight of the first driver if it acted alone. The bending moment at this point becomes $M = 0.69\ M_0 = 7.45\ P = 205\,000$ lb-in.

Bending Moment at Second Driver:

Effect of second driver	+ 1.00
Effect of first driver $\left(\frac{x}{x_1} = 1.94\right)$	— 0.20
Effect of third driver $\left(\frac{x}{x_1} = 1.94\right)$	— 0.20
Effect of fourth driver $\left(\frac{x}{x_1} = 3.88\right)$	— 0.05
Effect of pilot truck wheel $\left(\frac{x}{x_1} = 5.0\right)$ — 0.0 $\times \frac{12\ 500}{27\ 500}$	0.00
	0.55

The bending moment at the second driver is then 0.55 of that due to the weight of the second driver if it acted alone. The moment at this point becomes $M = 0.55\ M_0 = 5.94\ P = 163\,000$ lb-in.

Bending Moment at Trailer:

Effect of trailer load.................................. 1.00

Effect of fourth driver $\left(\frac{x}{x_1} = 3.53\right) = 0.08$

$\times \frac{27\,500}{20\,000}$ 0.11

Effect of first tender wheel $\left(\frac{x}{x_1} = 4.0\right) = -0.04$

$\times \frac{20\,000}{20\,000}$ .... − 0.04

+ 0.85

The bending moment at the trailer is then 0.85 of that due to the trailer load if it acted alone; and the bending moment is $0.85\ M_0 = 9.18\ P = 184\,000$ lb-in.

The method may be applied in a similar way to the determination of the bending moments at points away from wheel loads. The values of the negative bending moment may thus be found. Fig. 6 shows in a general way the distribution of bending moments for the conditions assumed in the preceding illustration and for the locomotive shown. The light lines show the moment produced by the individual loads; the heavy line is the resultant moment due to the combination of wheel loads.

If the weights on the several drivers differ, as in the case with the Mikado locomotive of the Illinois Central Railroad used in the tests, the difference in the wheel loads may easily be taken into account in the calculations.

The track depressions caused by the assumed locomotive loading may be calculated by a similar process.

At any point along the rail the components of track depressions caused by the individual wheel loads are found, and their algebraic sum gives the track depression resulting from the combination of loads. The values may be taken from Fig. 5 (which gives track depressions in terms of y_0, the depression under a single wheel load) for any given value of $\frac{x}{x_1}$, where x is the distance from the given point on the rail to the wheel load the effect of which on the track depression is to be determined, and x_1 is the distance from the wheel to the point of zero bending moment, in the case of a single wheel load. The values of the ratios thus found for the effect of the several loads may then be added algebraically; the product of this resultant ratio and y_0 is the resultant track depression due to the combination of loads. Fig. 6 illustrates the track depression for the Mikado locomotive used in the example illustrating the method of calculating bending moments. The light lines show the track depression produced by the individual wheel loads; the heavy line is the resultant track depression due to the combination of wheel loads. To illustrate the method of calculation, consider the case of the track depression under the first driver, as follows:

Effect of first driver.............................. + 1.00

Effect of pilot truck wheel $\left(\frac{x}{x_1} = 3.06\right)$ — 0.01

$\times \frac{12\,500}{27\,500}$...................................... — 0.00

Effect of second driver $\left(\frac{x}{x_1} = 1.94\right)$............. + 0.23

Effect of third driver $\left(\frac{x}{x_1} = 3.88\right)$............... — 0.04

+ 1.19

The track depression at the first driver is then 1.19 times that due to the weight of the first driver if it acted alone. Since y_0, the depression under the first driver acting alone (from Equation (9)), would be 0.00000774 P = 0.213 in. for the conditions already assumed for the track, the track depression at this point will be 1.19 y_0 = 0.254 in. The heavy line in Fig. 6 gives the resulting track depressions at all points along the locomotive. The vertical pressures may be found from the track depressions by the use of the modulus of elasticity of rail-support, u.

Figs. 7 and 8 give values of bending moment in rail and track depression for an Atlantic locomotive having the wheel loads and wheel spacing shown, the former for the worn 85-lb. rail section used on the test track, and the latter for the 125-lb. rail section, the value of u being 1 500 lb. per in. per in.

Fig. 9 gives values of bending moment in rail and track depression for a single car having the loads shown, and Fig. 10 gives values for the truck wheels of two adjacent cars, the rail being the worn 85-lb. section of the test track on the Illinois Central Railroad and the value of u being 1 500 lb. per in. per in.

It is seen that, by the method here described, the effect of a combination of two or more wheel loads on the track depression and the bending moment in rail may be determined for the condition of continuous support here assumed. It is evident that a second wheel load placed within a limited distance from another wheel will cause a smaller bending moment to be produced in the rail at the wheel, and likewise a larger track depression than would be produced with

BENDING MOMENTS AND TRACK DEPRESSIONS
FOR ATLANTIC LOCOMOTIVE, FROM ANALYSIS. 85-LB. RAIL

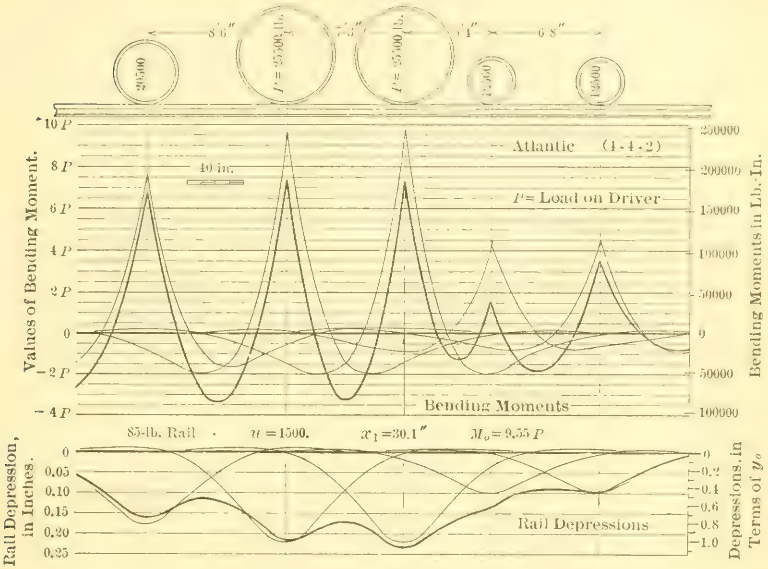


FIG. 7.

BENDING MOMENTS AND TRACK DEPRESSIONS
FOR ATLANTIC LOCOMOTIVE, FROM ANALYSIS. 125-LB. RAIL

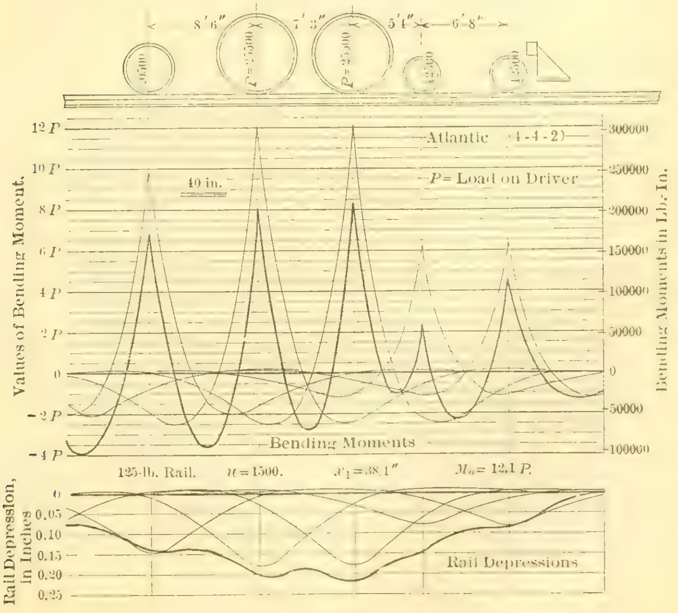


FIG. 8.

a single wheel load. The distance between wheels for which there will be a reduction in bending moment at the first wheel will depend on the rail section used and on the modulus of elasticity of rail-support. A third wheel within this limiting distance (usually on the other side of the first wheel) will also act to decrease still further

BENDING MOMENTS AND TRACK DEPRESSIONS
FOR LOADED CAR, FROM ANALYSIS, 85-LB. RAIL.

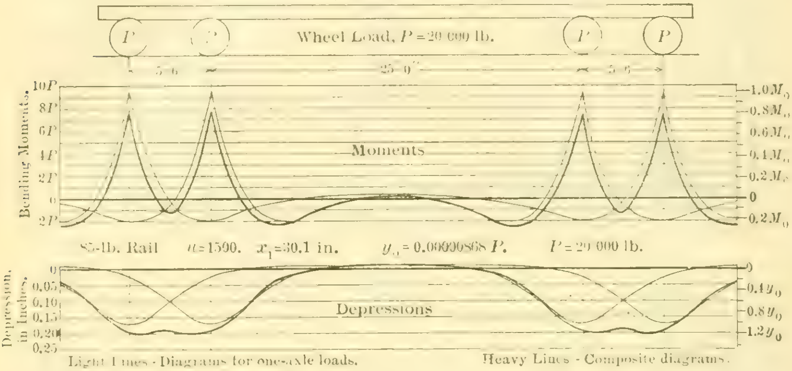


FIG. 9.

BENDING MOMENTS AND TRACK DEPRESSIONS
FOR TRUCKS OF TWO ADJACENT CARS, FROM ANALYSIS. 85-LB. RAIL

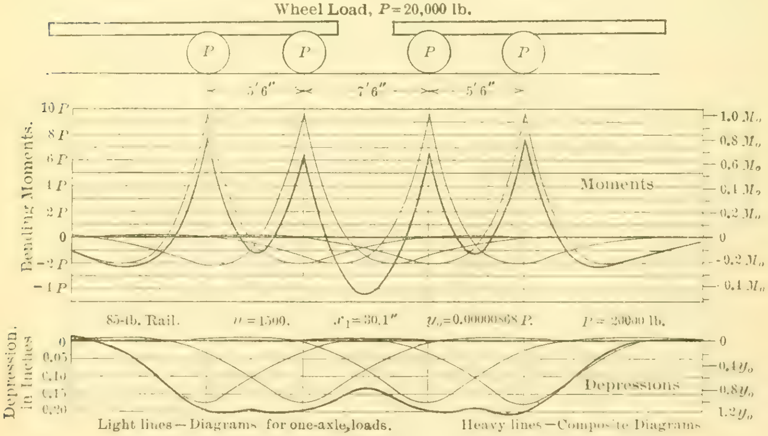


FIG. 10.

the bending moment in the rail at the first wheel. The effect of changes in the values of the moment of inertia of the rail section and of the modulus of elasticity of rail-support on the magnitude of the bending moments and track depressions will depend on the spacing of the wheels. For any given wheel loading and spacing, this effect may be readily determined.

7.—*Discussion of Applicability of Analysis.*—From the foregoing illustrations it is seen that the method of applying the analysis is not complicated. It is readily applied to determining the effect of a combination of wheel loads having any arrangement and any spacing, and takes into account the effect of the rail section used and the stiffness of the track. Although the cross-ties constitute a discontinuous support, their width forms a considerable part of the rail length, and, as the distance from a single wheel load to the point where the track depression is zero covers from four to six tie spacings, in such track as that on which the tests were made, the assumption of continuous support may not be expected to be generally much in error for the usual conditions of good track, especially as the method used for determining the value of the modulus of elasticity of rail-support will carry into this value some of the conditions attending the discontinuous support. Naturally, the magnitude of the modulus of elasticity of rail-support will depend on the size and spacing of the ties, the quality and depth of the ballast, the stiffness of the roadway, and the general condition of the track; and this property of track is one which must be determined by tests at different locations and under a considerable range of conditions.

It may appear at first thought that the assumption involved in the analysis—that the rail support is capable of developing negative pressures—may interfere with the accuracy of the results. Since there is play between the rail and the spikes, and since the ties cannot be expected to pull down on the rail, at least until there is some upward movement of the rail, there will be a region ahead of or behind a single wheel where little negative pressure may be developed in the track. However, in a combination of wheel loads, with the spacing usually found in locomotives, the effect of adjacent wheel loads in the analysis is such that there will be no negative pressure except ahead of the pilot truck wheel, and here the weight of the rail itself will assist in developing the negative pressure. In the case of cars, the analysis may give negative pressures at a point between the front and rear trucks of a car, but not between that of one car and the next. It may be expected that the absence of resistance to the upward movement of the rail, as shown by a rail lifting from the tie, will tend to increase the bending moment in the rail at the first wheel over that given if the negative pressure were developed.

Perhaps a more serious element affecting the accuracy of this analysis, and of any analysis which could readily be applied to combinations of wheel loads, lies in the fact that at small loads the magnitude of the track depression may be greater accordingly than at large loads; in other words, that the modulus of elasticity of rail-support is not a constant—a condition which may exist when the track is in a poorly tamped condition. However, for the heavier wheel loads, like the drivers and trailer, this influence may not be very important. For a condition where the modulus of elasticity of rail-support is not a constant, the principle of superposition, which is utilized in most methods of analysis involving flexure of structures, is not applicable, and hence any treatment based on the actual relation between pressure and depression will be altogether too complicated for any practical use.

It may not be expected that any method of analysis will give results that will fit accurately with experimental values. The variables of track are numerous and uncertain. Notwithstanding this, a usable analytical treatment is of great value in the comparison of experimental data and in acquiring a conception of the fundamentals of track action. It is believed that the analysis here given is acceptable from most points of view. Possibly in the future it may be found practicable to make empirical modifications of it which will fit more closely the data of tests.

III.—The Conduct of Tests.

A.—Apparatus, and Method of Conducting Tests.

8.—General Requirements for Test Apparatus.—An experimental study of stresses in railroad track involves the measurement of deformations or strains in rails, pressures existing at various points throughout the ballast, deflection of rails, depression and bending of ties, and depression at various points in the ballast and the roadway, when acted on by a load. As the study of the effects of different kinds of loading, such as one-axle loading, two-axle loading, loading with locomotives of different wheel spacing applied both statically and at various speeds, was an essential part of the undertaking, it was necessary that the design of the instruments be made suitable for use under the diverse conditions of the various tests.

In the design of instruments, simplicity and reliability in operation rather than extreme sensitiveness were considered the prime requisites for measurements of strains, pressure, and depression. The instruments must be designed so that they will operate satisfactorily under variable weather conditions and give reliable results when used amid considerable dust and dirt. Some instruments are attached to rails subjected to severe vibration under rapidly moving locomotives; others are of necessity left buried in ballast for weeks at a time. As thousands of observations were taken, and as the instruments had to be adjusted or moved frequently in the short time between the passage of trains on a busy track, the importance of simplicity and rapidity of operation can hardly be over-emphasized. The dust and dirt unavoidably present would greatly lessen the reliability of instruments using complicated, delicate mechanism.

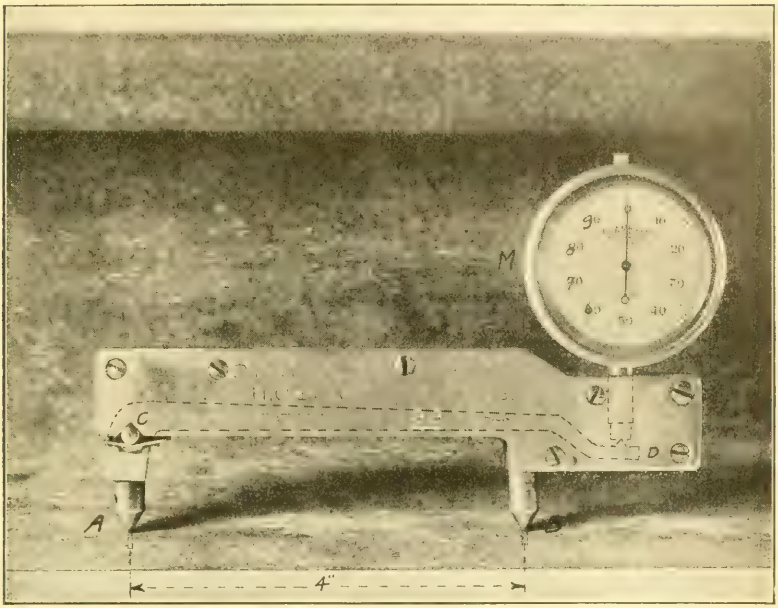


Fig. 11.—Berry Strain Gauge.

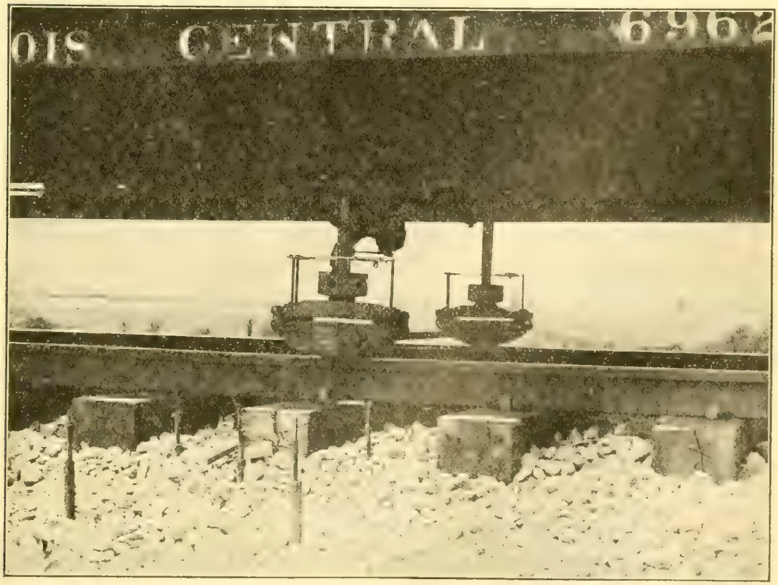


Fig. 12.—Load-Indicating Jacks in Position for One-Axle Load Test.

Nearly all the instruments used were designed especially for this work. To meet the severe conditions of field tests, they differ from the forms which might be suitable for those to be used under laboratory conditions. This difference is especially great for those used under rapidly moving loads. In many respects the problems involved in their design were new, and in some cases many attempts were made and a number of forms were tried out before satisfactory results were obtained. Much time was spent in experimenting with various forms of instruments to meet the needs of existing conditions. Details have been changed from time to time as improvements were devised. Those described herein show the final form chosen after the various modifications of details. In all cases they have given consistent results, have been found to be sufficiently sensitive to permit satisfactory interpretation of test results, have been accurate within the limits which were thought necessary and desirable, and have proved reliable and simple in operation.

9.—The Strain Gauge and Its Use in Measuring Strain in Rails Under Static Load.—In the tests with static loading, longitudinal strains in the rails under bending load were measured with a Berry strain gauge, Fig. 11. The strain gauge measures the change of distance between two small drilled holes, *A* and *B*, called the gauge points, which lie at the two ends of a gauge line along which the strain is to be measured. To the frame of the strain gauge are attached a dial micrometer and two pointed legs; one leg, *B*, is attached rigidly to the frame; the other leg is pivoted to the frame. The pivoted leg forms one arm of a bent lever, *A-C-D*, the other arm of which bears against the dial micrometer, *M*, which is attached to the frame of the instrument. The pointed ends of the legs of the instrument are placed in the gauge holes, and the reading of the micrometer dial is noted. This is done both with no load and with a given load. For any gauge line, the total strain is given by the difference between the reading under no load and the reading under load.* The general method of using this instrument consists in taking readings on a series of gauge lines with no load on the rail, and then taking a series of readings on the same gauge lines with a known load on the rail. For accurate work, this instrument requires the touch and care of a skilled operator. The unit strain is found by dividing the total strain by the length of the gauge line, and the longitudinal stress is determined by multiplying the unit strain by the modulus of elasticity of the steel, which, for the purposes of these tests, has been taken as 30 000 000 lb. per sq. in. The length of the gauge line used was 4 in. The gauge holes at the ends of each gauge line were drilled about $\frac{1}{16}$

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* For a more detailed discussion of the strain gauge and its use, see *Bulletin 64*, Engineering Experiment Station, University of Illinois, "Tests of Reinforced Concrete Buildings under Load", by Talbot and Slater, and *Proceedings*, Am. Soc. for Testing Materials, 1915, p. 1019, "Use of the Strain Gauge in Testing Materials", by Slater and Moore.

in. deep with a No. 54 drill (0.055 in. in diameter) and were in the top of the base of the rail about ¼ in. from the edge. (See Fig. 11.)

10.—The Level-Bar, and its Use in the Measurement of Rail Deflection and Tie Depression under Static Load.—For measuring the deflection of rail and the depression and bending of ties, the level-bar shown by Fig. 13 was used. It is a modification of an instrument used by Dr. P. H. Dudley, Consulting Engineer of the New York Central Lines, for determining tie and rail depressions, differing from Dr. Dudley's instrument in the length of bar and in the micrometer device. The distance between the two conical points, *A* and *B*, was 20 in.

In use, *A* is placed on a reference point, and *B* is placed on the spot for which the deflection is desired. The leveling nut, *N*, is then turned, raising or lowering the plunger, *P*, until the horizontal bar stands level, as shown by the level bubble. The dial micrometer, *M*, is attached to the plunger, *P*. A reading of the dial micrometer is taken without load and another with load. The difference between the two readings gives the change in elevation at one point with respect to the other. In cases for which a constant gauge length of 20 in. was not convenient, instead of resting the instrument on *A*, the longitudinal slot in the horizontal bar is placed on a projecting point, such as the pointed rod of a depression plug (*Q*, in Fig. 28). The determination of the deflection by the use of the level-bar is not affected by the distance between reference points.

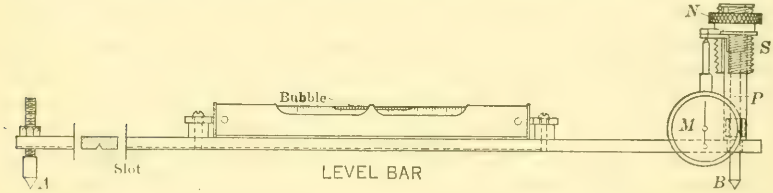


FIG. 13.

11.—The Depression-Plug, and its Use in the Measurement of Depression in Ballast and Roadway.—In order to measure the depression under static load of the ballast at various points and depths, and also the depression of the roadway, the device shown at the left in Fig. 14 was used. This device is called a depression-plug. It consists of a plate, *P*, about 3 in. square, to which is attached a tube, *T*, with a rod, *Q*, which is adjustable for height. The plate, *P*, is placed in the ballast, or over the roadway where the depression is to be measured, and the outer tube, *S*, is placed over the tube, *T*. Direct contact of *T* with the ballast would cause friction between them, and consequently the depression of *P* would be affected. The enclosing of *T* with *S* prevents this. The lower end of the outer tube, *S*, is raised an inch or two above the plate, *P*. As depression occurs at *P*, the rod, *Q*, is depressed an equal distance, and the depression may be measured with the level-bar.

For measuring the depressions directly under a tie, the double depression-plug, shown at the right in Fig. 14, was used. The action of this plug is the same as that of the single depression-plug. The average of the depression, indicated by readings taken on both rods of the double plug, was taken as the average depression at the middle of the width of a tie.

12.—The Pressure-Capsule, and its Use in the Measurement of Pressure in Ballast.—For measuring the pressure transmitted to various parts of the ballast, the pressure-capsule shown by Fig. 15 was used. The elastic deflection of a thin steel diaphragm is used to measure the pressure applied to the capsule. The pressure to be measured is received on the bearing plate, *P*, which has an area of 5 sq. in.; the pressure is transmitted to the thin steel diaphragm, *D*, which is fastened by screws around its circumference to the cast-iron case, *B*. The screw, *S*, which fastens the plate, *P*, to the diaphragm, *D*, is hardened, and bears on one knife-edge of the small bell-crank lever, *L*, which is pivoted at *Q*. The vertical deflection of the center of the diaphragm is transmitted by the bell-crank lever (magnified about three times) in a horizontal direction to the rod, *R*, which slides in the guides, *NN′*, and is enclosed in a horizontal tube, *K*, and finally bears against the plunger, *T*, of an indicating dial micrometer, the

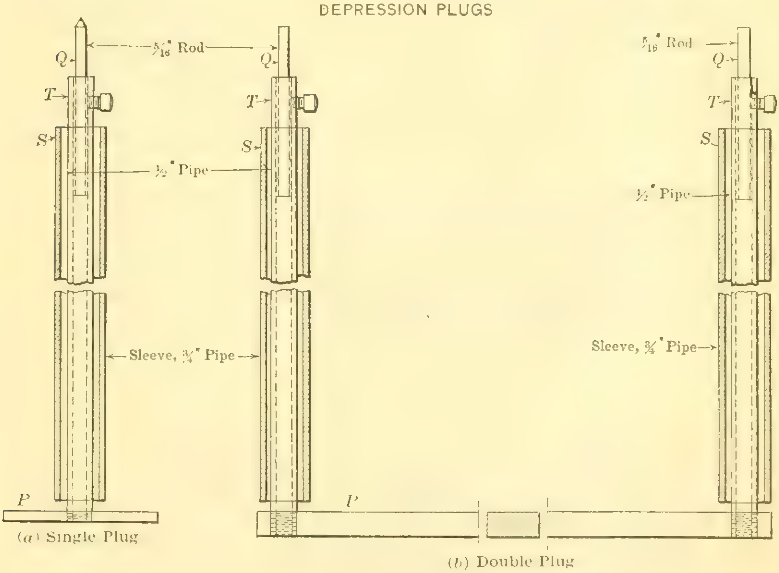


FIG. 14.

movement of which is thus a measure of the elastic deflection of the diaphragm, *D*. If the material of the diaphragm is not stressed beyond its elastic limit, the deflection of the diaphragm, and the consequent movement of the pointer of the dial micrometer, may be used to measure the load on the plate, *P*. Each pressure-capsule was calibrated by placing it on a platform scale and, with a screw clamp, applying a series of loads covering the range of its use. The instrument was recalibrated after use. The dial of the micrometer was arranged so as to be adjusted to read zero at zero load. This does away with the need of applying a correction for zero reading.

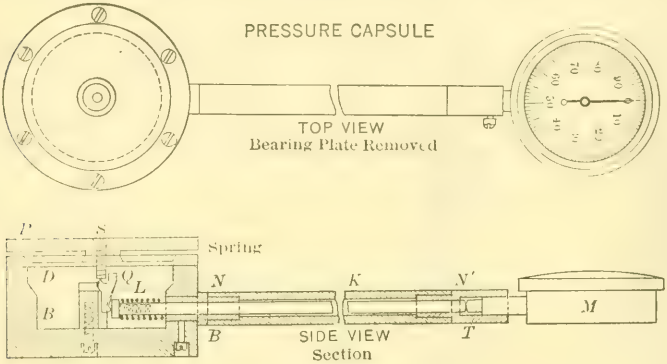


FIG. 15.

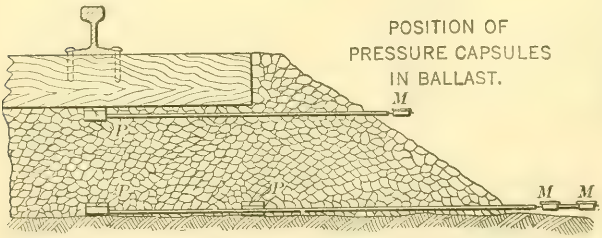
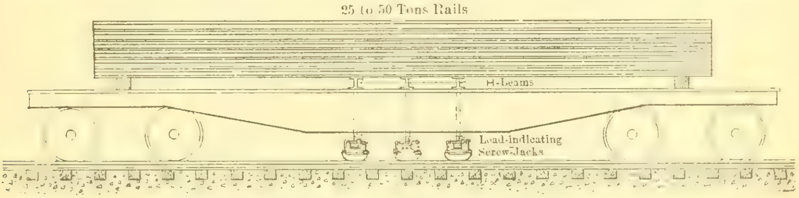


FIG. 16.

The thin elastic diaphragm is made of hardened steel. The bearing plate served to take a load of any distribution or concentration on it, and to apply this load as a concentrated load at the center of the diaphragm.

This form of pressure-capsule was adopted after trying various other devices. In one instrument tried, a capsule was filled with water, and the deflection of the cover was measured by the quantity of water forced into a small tube connected with the capsule. This instrument proved to be inaccurate under varying temperatures. In another form, the deflection of the cover of the capsule acted on the ends of a slightly bent spring, and the lateral motion of the spring was measured. This form was less sensitive than that shown by Fig. 15. Attempts were made to measure pressures by the varying electrical conductivity produced in various substances by variations in pressure, but this did not give satisfactory results.

The position of the pressure-capsules as placed in the ballast is shown by Fig. 16. At the spot where it is desired to measure the pressure, a capsule is placed, with the surface of the bearing plate, *P*, perpendicular to the direction of the pressure to be measured. Above the bearing plate is spread a cushion of fine material to guard against undue concentration of pressure from large pieces of ballast. The horizontal tube, *K*, with its enclosed rod, extends outside the ballast, and at its end carries the dial micrometer, *M*. The total pressure carried by the bearing plate, *P*, when load is applied to the track, is indicated by the reading of the micrometer dial, and the intensity of pressure for that spot in the ballast is found by dividing the total load on the pressure-capsule by the area of the bearing plate, *P*. Sand and dirt are prevented from coming between the bearing plate, *P*, and the diaphragm of the instrument by friction tape wrapped around the case of the pressure-capsule.

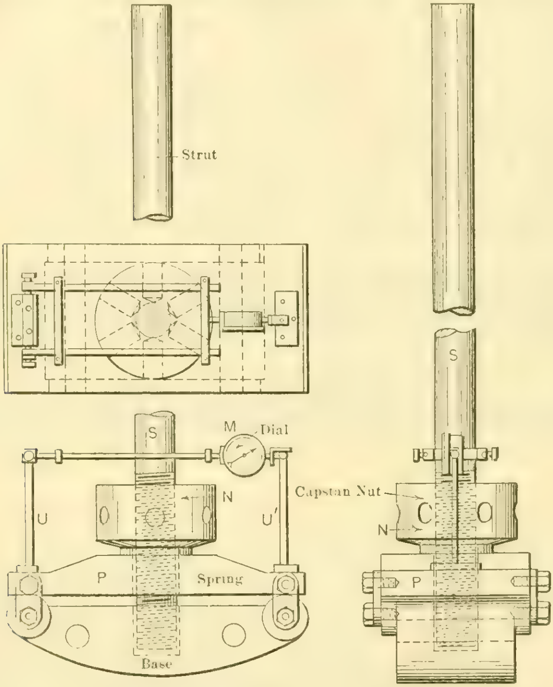


LOADING APPARATUS FOR ONE-AXLE AND TWO-AXLE LOADS.

FIG. 17.

13.—Indicating Jacks, and Their Use in Applying One-Axle and Two-Axle Loads.—For applying loads equivalent to a one-axle or a two-axle load, a flatcar loaded with from 25 to 50 tons of rails was used in connection with special load-indicating screw-jacks. As shown in Fig. 17, the rails on the car were supported on **H**-beams placed crosswise of the car. Against the bottom of these **H**-beams the upper ends of the indicating screw-jacks bore. The lower ends of the screw-jacks bore against the rails through curved bearing blocks having a radius approximating that of an ordinary car wheel, but not coned. On Fig. 17 the location of the indicating screw-jacks is shown in solid lines for the two-axle, and in broken lines for the one-axle, loading.

The construction of the load-indicating screw-jacks is shown in detail on Fig. 18. The load is applied by turning the capstan nut, *N*, on the screw, *S*, and the load is measured by the inclination given to the ends of the flat nickel-steel spring, *P*. As this spring deflects under load, the ends are inclined, and with them the uprights, *U*, *U′*. The distance between the tops of the uprights is lessened, and the length of the motion is indicated by the dial micrometer, *M*. The load-indicating screw-jacks were calibrated in the laboratory by loading them with known loads in a testing machine. Stresses and depressions were generally measured for one rail only, but, in order to have both rails symmetrically loaded, it was necessary to use load-indicating jacks on both rails. Fig. 12, from a photograph, shows the jacks in place under the car of rails ready for the application of a one-axle load.



DETAILS OF LOAD-INDICATING JACK
FIG. 18.

14.—The Stremmatograph, and its Use in Measuring Rail Strains.— In order to measure the strains in rails under moving locomotive loads, it is necessary to use recording instruments, as the motion of an indicating pointer would be too rapid to be followed accurately by the eye. Recording instruments for track tests under rapidly moving loads must withstand severe vibration, must be used in places exposed to dust and dirt, and must permit a large number of readings to be taken. It is evident that some simple form of recording device is essential, one with few parts, one which may be quickly attached in position, and one giving a record which may be read quickly and accurately.

Various types of recording instruments were considered before deciding on the one to be used. Instruments with multiplying levers were regarded as unsuitable; experience with recording instruments has shown that uncertain effects are introduced by the inertia of moving parts, if the load is applied rapidly. Instruments involving the use of a ray of light reflected from a mirror to a sensitized photographic film were considered. This type gives the highest degree of sensitiveness of any considered, but its use would involve rather cumbersome arrangements of light-proof tubes leading from the mirror to the film; a special source of light would be necessary, and much time would be required to develop the films. A very ingenious mirror-type extensometer was designed and constructed by Mr. W. M. Dawley, and this instrument may be of great service in case very delicate measurements of strains are found to be necessary in the development of further tests. In general, however, for track tests, the use of mirror-type instruments with photographic records would consume too much time, and they would be too likely to get out of adjustment under field conditions.

For general use in measuring rail strains, it was decided to use an instrument involving the general principle utilized in the stremmatograph developed by Dr. P. H. Dudley. In Dr. Dudley's instrument*, a sharp steel point draws a diagram on a flat plate of polished phosphor-bronze. No mechanical multiplying device is used, and the motion of the recording point across the bronze plate (ordinates of the diagram) is equal to the strain in the rail between gauge points. The latter were placed on the under side of the base of the rail, near the outer edge; measurements were not made along the inner edge. The bronze plate is given a rectilinear motion at right angles to the motion of the recording point by a screw-drive. The record graven on the bronze plate is examined under a high-power microscope, and the strain at any desired point on the record, given by the height of the diagram, is measured with a filar micrometer eye-piece.

The instrument used by the Committee differs in several important details from the stremmatograph described above. When the record is made on a bronze plate, the scribing needle must be re-ground after taking a few records. This re-grinding was a slow process, requiring a high degree of skill. After experimenting with various methods, it was decided to make the records of strain on a glass disk very lightly smoked. It was found that a steel needle sweeps a smooth-edged, sharply-defined path through the very fine particles of lampblack which coat the disk, and that the width of such a path is very uniform.

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* The following articles by Dr. P. H. Dudley give some results of tests made with his stremmatograph:

"Stresses in Rails under Moving Loads", *Railroad Gazette*, May 20th, 1898.
"Stresses in Railway Track under Moving Trains", *Engineering News*, Oct. 6th, 1898.
"Stresses in Rails under Moving Loads", *Railroad Gazette*, Oct. 21st, 1898.
"Rail Stresses—Tests of Unit Fiber Strains", *Engineering News*, Nov. 14th, 1901.
"Stremmatograph Tests, etc.", *Bulletin*, Int. Railway Congress, June, 1904.

After experimenting with various kinds of needles, it was found that a steel phonograph needle was suitable for making stremmatograph records on smoked glass, and they were inexpensive and could be readily obtained. Phonograph needles as purchased were found to be too hard and brittle, and, before being used, the temper was drawn slightly by heating them in oil at a temperature of 536° Fahr. (280° cent.) for 30 sec. and then quenching in water.

In order to give length to the record the disk was given a rotary motion, instead of the rectilinear motion used by Dr. Dudley, and a circular diagram was drawn, rather than a straight-line diagram. Freedom from play in bearings is of the very highest importance for securing accuracy in such an instrument. Bearings for circular motion can be made free from perceptible play more easily than can those for straight-line motion. The plane of the record disk is vertical. The most serious vibration of the rail is the up and down motion; this has the least dulling effect on the needles, and causes the least variation in the width of the line, if the plane of the record disk is vertical.

For smoking the glass disks used in the stremmatograph and other recording instruments, gasoline was used. Of all the various coatings tried, it was found that the smoke from burning gasoline gave one on which the needle scratches left the sharpest, clear-cut lines. In smoking the disks, they were held in a special device and passed back and forth through the smoke. The gasoline was burned in a small open cup holding about 2 oz.

As the tests progressed, various details of the stremmatograph were altered. The latest form of this instrument is shown by Fig. 19. Two clamps, *A* and *B*, are attached to the base of the rail, 4 in. apart, and between them extend two needle-bars, *NN*. One end of each needle-bar is in the shape of a spherical head with a slender stem; the other end is clamped by a set-screw to the clamp, *A* (called the anchor clamp); and the spherical end of each needle-bar is free to slide in a brass sleeve in the clamp, *B* (called the record clamp). Any point on the needle-bar will move with respect to any point on the record clamp, *B*, a distance equal to the stretch or the shortening of the rail along the line of the needle-bar. With the instrument shown, records are obtained for strains along both the inner and outer edges of the base of the rail.

In the first design, measurements of strain were made on only one side of the rail, but, when it was found that there was an appreciable difference between the stresses on the two sides of the rail, the design was altered so as to include measurements on the two sides.

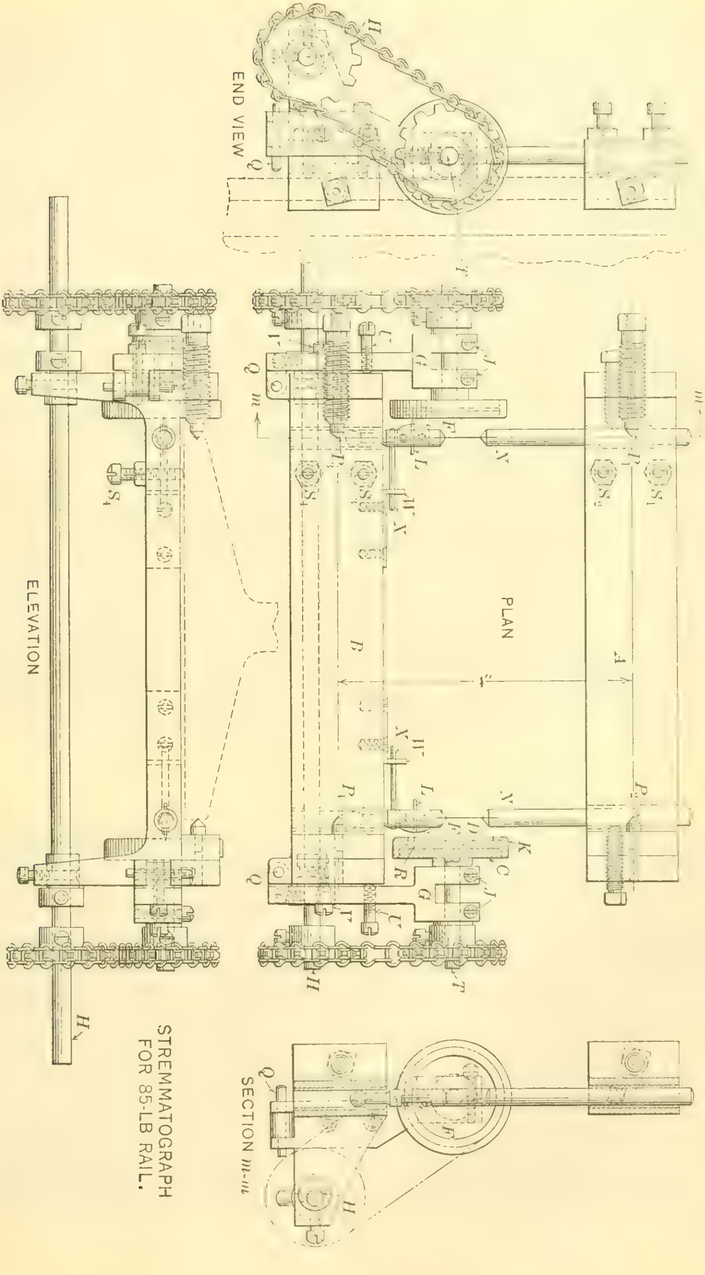
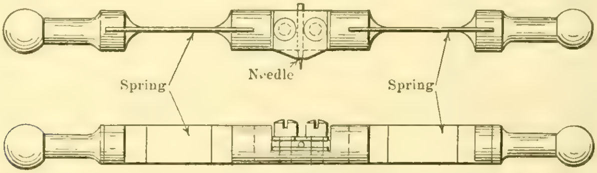


FIG. 19.

STREMMATOGRAPH FOR 85-LB RAIL.

Each of the clamps, *A* and *B*, is fastened to the base of the rail by one set-screw and one fixed, hardened-steel point. The clamps are prevented from pivoting or rotating about the clamping points by the steadying screws S_1, S_2, S_3, and S_4, which bear against the bottom of the rail. The brass sleeves in the clamps are placed so that the center lines of the needle-bars come directly under the inner and outer edges of the base of the rail. The fit of the sliding end of a needle-bar in its guide-sleeve must be made with care. Each needle-bar is fitted with a brass clamp plate, *F*, which holds a hardened phonograph needle, *L*, and this bears against the smoked-glass record disk, *D*. It is necessary that the needle-bars shall be rigid in a vertical plane, and that they shall have considerable "spring" in a horizontal plane, so that an even pressure of the needle-point against the record disk may be maintained. This combination is effected by making a part of each needle-bar a thin flat spring with the width vertical. To prevent turning, the sliding end of each needle-bar is held by a pin, *X*, which slides in a guide-slot, *W*.



EARLY TYPE OF NEEDLE-BAR FOR STREMMATOGRAPH

FIG. 20.

In the development of the stremmatograph, various types of needle-bars were tried. First a bar without any spring was tried, but did not give satisfactory records. Next, the type shown by Fig. 20 was used. This was fitted with two springs, and gave better records than the stiff bar, but, at high speeds, it "chattered" and caused the needle to cut into the glass record disk. It was found later that this type of bar had an appreciable "lag", due to excessive flexibility in a horizontal plane; the result of this is that the results obtained are somewhat small. Practically all the records of 1915 were obtained with instruments fitted with bars of this second type. The change to the later type accounts for the improvement in the consistency of the results of the tests of 1916 over those of 1915. The tests of 1916 and all subsequent ones were made with instruments fitted with the form of needle-bar shown by Fig. 19.

Each of the smoked-glass record disks on which the records of strain are taken, is clamped against a face-plate, *C*, with a screw-cap *K* (Fig. 19). Between the record disk and the face-plate is placed a circular piece of sheet-rubber, *R*. Each face-plate is driven by a shaft, *T*, which rotates in double bearings, *G*, and is itself driven by a sprocket and chain from a drive-shaft, *H*, below the instrument.

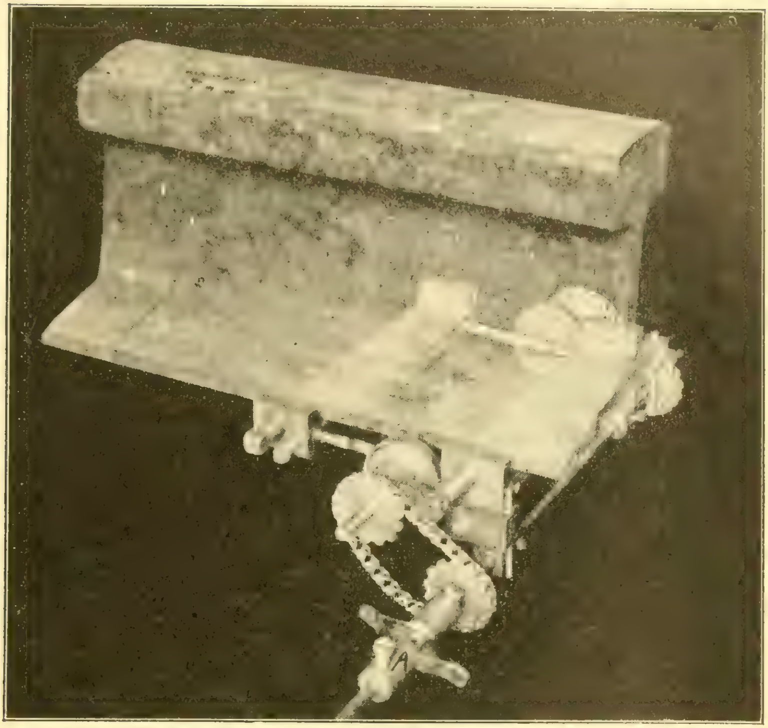


FIG. 21.—STREMMATOGRAPH IN POSITION ON RAIL.

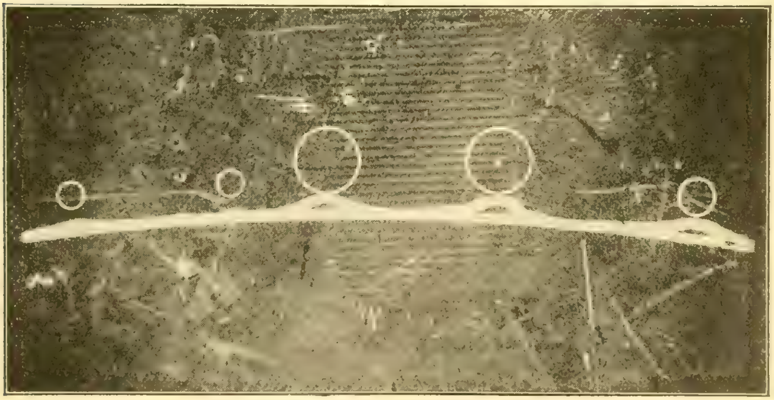


FIG. 22.—PHOTOMICROGRAPH OF STREMMATOGRAPH RECORD.

This drive-shaft turns in eccentric bearings which permit adjustment of the chain tension, and is driven, through a flexible-spring coupling (shown at *A*, Fig. 21), by a long shaft which extends to one side of the track.

It is of highest importance that all play be taken up in the bearings of the drive-shaft, *T*, as any radical play is recorded as strain on the smoked-glass disk. The double bearings, *G*, were ground to fit the shaft, *T*, and the split bearings were fitted with tightening screws, *J*, for taking up wear. In order to eliminate all play, the bearings were tightened on the shaft so that the latter drove with considerable friction. Washers and collars were used to prevent axial play.

For convenience in changing disks or needles, the bearings, *G*, for the disk-shaft, *T*, were attached to the clamp, *B*, with a tapered pin, *Q*, which served as a pivot around which the bearings, disk-shaft, face-plate, and disk could be swung, so that the screw-cap, *K*, could be unscrewed, the smoked-glass disk removed, and another substituted, or so that the needle could be changed or adjusted. When in position for taking records, the bearings, shaft, and disk were clamped fast by the clamp screws, *U* and *V*.

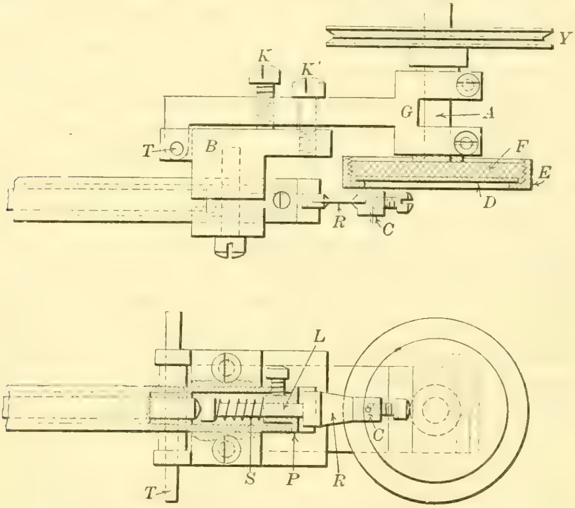
Fig. 21 is from a photograph of a stremmatograph in position on a rail. That part of the instrument behind the rail is shown by making a double exposure of the photographic plate used in taking the picture. Fig. 22 is from photo-micrographs of typical stremmatograph records. The zero line was obtained by giving the record disk one complete revolution with no load on the track. The height of the strain diagram is measured from this zero line.

As the records of strain were obtained for both edges of the base of the rail, it was necessary to make the clamps fit the particular size of rail on which the stremmatograph was to be used. Except for the clamps, the details of the instruments are the same for all sizes of rail.

Instruments were made covering 56-lb., 75-lb., 85-lb., and 100-lb., Am. Soc. C. E. sections, the 125-lb. Pennsylvania Railroad section, and the 136-lb. Lehigh Valley Railroad section. Fig. 19 shows the instrument used for the 85-lb. Am. Soc. C. E. rail. Usually, for any test, four instruments were used at one time.

15.—The Recording Pressure-Capsule.—For recording pressures under moving load at various points in the ballast, recording pressure-capsules were used. These differed from those used for static tests only in the substitution of recording devices for the dial micrometers used with the pressure-capsules for static loads, which are shown by Fig. 14. Fig. 23 shows the recording device for the instrument for tests with moving loads. In the end of the horizontal tube which extends sidewise from the pressure-capsule is fastened a bearing plug, *P*, in which slides a plunger, *L*, which is normally held in its innermost position by a spring, *S*. At the outer end of the plunger, *L*, is fastened a flat spring, *R*, with its width vertical, and at the outer end of this flat spring is a needle-chuck, *C*, in which a needle is held by a set-screw.

A block, *B*, is clamped on the outer end of the horizontal pipe extending from the pressure-capsule. To this block is fastened, by a tapered pin, *T*, and clamping screws, *K* *K′*, a double bearing, *G*, in which turns a shaft, *A*, to which is attached a face-plate, *F*, on which a smoked-glass disk, *D*, is clamped by the screw-cap, *E*. The bearing, the face-plate, the disk, and the screw-cap are the same as the corresponding pieces used with the stremmatograph. For the recording pressure-capsule, the disk shaft, *A*, is driven by a round belt operating the grooved pulley, *Y*. The deflection of the diaphragm of the pressure-capsule causes a motion of the plunger, *L*, which, in turn, causes motion of the needle. The motion of the needle draws the diagram as the smoked-glass disk, *D*, is turned and the moving load passes the instrument. The radial ordinates of this diagram, measured from a base circle for zero load, are proportional to the deflection of the diaphragm of the pressure-capsule, and hence are a measure of the pressures at the point in the ballast where the capsule is placed. The measurement of the radial ordinates of pressure-capsule records is made with a microscope fitted with a micrometer eye-piece.



RECORDING DEVICE FOR PRESSURE CAPSULE

Fig. 23.

When the pressure-capsule was being designed, little attempt was made to work out the details of an instrument which would operate satisfactorily under moving loads, as only static-load tests were being made. Later, the recording device was designed for use with the pressure-capsules under moving loads, and a number of tests were run.

It is thought, however, that, due to the inertia of parts in the instruments, measurements of pressures under moving loads at speed will be inaccurate and unreliable, especially at high speeds.

16.—Drive Rig for Moving-Load Tests.—The drive apparatus for turning the disks of the recording instruments in the moving-load tests is shown at one side of the track in Fig. 25. The main drive-shaft is driven by hand, through a crank and worm reducing gear, and this, in turn, drives small shafts which are connected with the several stremmatographs. Although the attempt was made to have the speed of rotation of the drive about proportional to the speed of the locomotive, this was not considered a very important matter. As long as the drive was fast enough to separate the portions of the curve corresponding to the passage of successive wheels, no trouble was encountered in reading the various strains from the curves, nor was it necessary to have a means for establishing the position of the locomotive with respect to the location of the instrument, other than that given by the records themselves. As can be seen from Fig. 22, the records show definite maximum values in the curves corresponding to the passage over the instruments of various wheels of a locomotive. It is obvious that such a maximum value can only occur when a wheel is over the instrument, so that it is unnecessary to have other means for determining the position of the locomotive.

17.—Measurement of Deflection of Rail with a Camera.—In moving-load tests, the deflection of various points of the rail was measured by using a double-exposure photograph. At intervals there were glued along the outside of the rail small pieces of black paper with small white crosses on them. A Speed Graphic camera for 5 by 7-in. plates was set up at a distance of about 10 ft. from the rail, as shown by Fig. 25. At this distance the vibration of the camera was found to be small, and it did not affect the results of the measurement materially, except at high speeds. The camera was fitted with an anastigmat lens having a speed of F 4.5 and a focal-plane shutter giving a minimum length of exposure of 0.001 sec. For any given observation, a photograph was made of the unloaded rail with its attached white crosses. Then, without moving the camera or changing the plate, the camera shutter was set for the next exposure. The camera shutter was fitted with an electro-magnet release, and the wires from the magnet led through a battery to a contact piece attached to the rail. As the locomotive ran on the test section of track the front truck, as it passed over the contact piece, closed the circuit through the electro-magnet, and a second photograph of the rail, with its attached white crosses, was made on the plate in the camera. On the plate, when developed, each small white cross shows as a vertical line crossed by two horizontal lines, and the distance between the horizontal lines is proportional to the depression of the rail. This distance was measured with a microscope having a micrometer eye-piece, and multiplication by a factor gave the rail depression.

With one camera the depression of the rail may be measured for a length of about 10 ft. Generally, two cameras were used, both operated at the same time by the magnetic release. In examining the developed photographic plates with a microscope, the maximum magnification used was about 75 times. Under higher magnification, the silver grains on the sensitized surface of the plate showed as small particles to such an extent that the edges of the lines of which the distance apart was to be measured were blurred. With the camera 10 ft. from the track, and a magnification of 75 in the measuring microscope, the deflection of the rail can be determined with a precision of about 0.01 in.

For this photographic measurement, Cramer Crown, single-coated, photographic plates were used. These plates were found to combine high sensitiveness to light with fine grain of silver. Fig. 24 is from a print of a double-exposed plate for depression measurement.

18.—Measurement of Speed of Locomotive.—For measuring the speed of the locomotive as it passed the test section of track, an automobile speedometer of the revolving-magnet type was used. The speedometer was driven, through a flexible shaft, by a leather-faced friction wheel which ran on the tread of a wheel of the locomotive, generally the trailer. The speedometer was placed so that its dial was visible to the engineman and to an observer stationed in the cab. The accuracy of the speedometer was checked at various speeds by noting its reading while the locomotive was run at various uniform rates of speed over a stretch of track, the time being measured by a stop-watch. The friction-drive wheel of the speedometer was pivoted, so that it could be swung back out of contact with the wheel when the locomotive was run backward. When in operating position, the friction-drive wheel was held against the wheel by a spring.

19.—Manufacture of Instruments.—The strain gauge, the cameras for recording depression of track, the microscopes for reading records from recording instruments, and the speedometer, were purchased. The load-indicating jacks and the depression plugs were made by local firms from designs furnished. All other instruments were made in the shop of the Laboratory of Applied Mechanics of the University of Illinois by the mechanician employed on the test work. In all, there were manufactured 14 stremmatographs, 2 level-bars, 73 pressure-capsules, and various special appliances and connecting parts for apparatus. It should be stated that, after the instruments had been first made, it was necessary for the mechanician to spend considerable time in maintaining the instruments and in making such modifications as were found to promise better results.

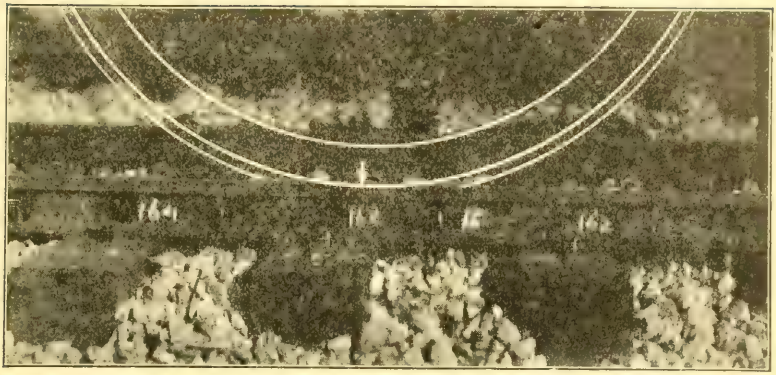


FIG. 24.—DOUBLE-EXPOSURE PHOTOGRAPH, AS USED IN MEASURING TRACK DEPRESSION.

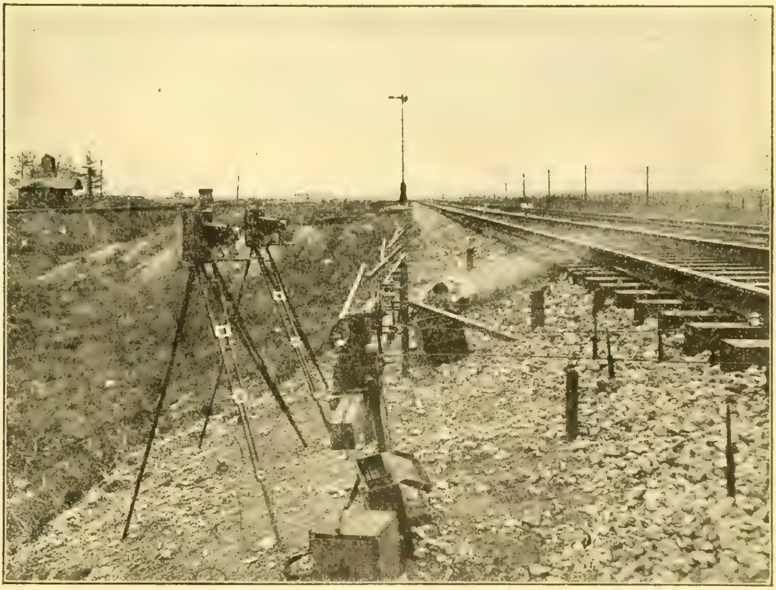


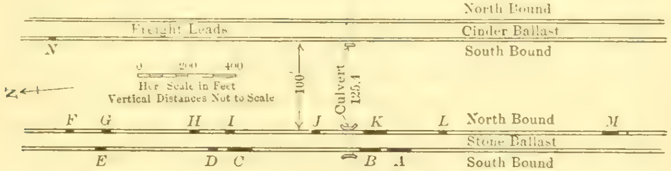
FIG. 25.—TEST SECTION ON ILLINOIS CENTRAL RAILROAD.

B.—Preparation of Test Track, and Procedure of Tests.

20.—Test Sections on Illinois Central Railroad.—The track of the Illinois Central Railroad used in the test work is on the double-track main line, about 2 miles north of Champaign, Ill. At this location all freight trains are diverted from the main-line tracks, and run through the yards over special freight tracks, only passenger trains being run over the main line. For test purposes, therefore, these tracks are comparatively free from traffic disturbances.

The stretch of track used is on an embankment, from 4 to 8 ft. high, composed of loam and clay. A single-track road was built in 1854, and the second track was added in 1900. Age has given compactness to the embankment, and it was in dry condition throughout the tests.

The ballast at this place consists of crushed limestone; it usually has an average depth under the ties of about 12 in. The rails are Am. Soc. C. E. section, 85 lb. per yd. The rails on the south-bound track are 33 ft. long, and were laid in 1902; those on the north-bound track are 30 ft. long, and were laid in 1900.



RELATIVE LOCATION OF TEST SECTIONS
ON ILLINOIS CENTRAL RAILROAD

FIG. 26.

To provide uniform known conditions of track for the tests, four stretches were specially prepared. For these test sections special oak ties replaced the original ties. Four such sections were prepared within a short distance of each other. On one section the ballast had a depth of 6 in. below the ties; on another, 24 in.; and on two others, 12 in. On one of the last-named sections the ties were 7 by 9 in. by 8 ft.; on all others they were 6 by 8 in. by 8 ft. In locating the test sections, depths of ballast closely approximating those desired were found, and the track was raised to make the proper depth. The special ties had been prepared accurately to size, and were of uniform quality. When first prepared, these special test sections were laid with the 85-lb. rail which had been in the track originally. Later, when it was desired to use heavier rails in the tests, these were removed and replaced by the heavier ones the sections of which are shown on Fig. 107. The sections used were chosen because they were readily available, and give considerable range in weight. The relative location of the various test sections is shown in Fig. 26. The size of rails used is given in Table 1. The 100-lb. rails were placed on Section *K*, which has 24 in. of ballast and 6 by 8-in. by 8-ft. ties. The 125-lb. rails were placed on Sections *B* and *K*, which have 12 and 24 in. of ballast, respectively, and 6 by 8-in. by 8-ft. ties.

TABLE 1.—Description of Test Sections on Illinois Central Railroad.

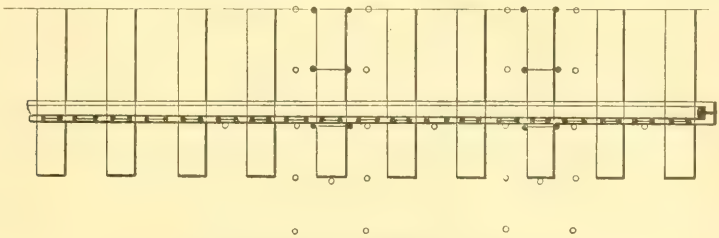
Section.	Rail.	Ties.	Ballast.	Remarks.
A	85 lb.	Sp'l. 7 by 9 in. by 8 ft. 0 in.	12-in. stone.	Special section.
B	85 and 125-lb.	Sp'l. 6 by 8 in. by 8 ft. 0 in.	12-in. "	do.
C	85-lb.	Sp'l. 6 by 8 in. by 8 ft. 0 in.	6 in. "	do.
D	do.	About 6 by 8 in. by 8 ft. 0 in.	About 6-in. stone.	Ordinary track.
E	do.	do.	do	Decayed tie.
F	do.	do.	do.	do.
G	do.	do.	do.	do.
H	do.	do.	do.	Tie-plates used.
I	do.	do.	do.	Decayed tie.
J	do.	do.	About 24-in. stone.	Ordinary track.
K	85, 100 and 125-lb.	Sp'l. 6 by 8 in. by 8 ft. 0 in.	24-in. stone.	Special section.
L	85 lb.	About 6 by 8 in. by 8 ft. 0 in.	About 15-in. stone.	Decayed tie.
M	do.	do.	" 8-in. "	do.
N	do.	do.	" 6-in. cinder.	Freight lead.

In order to check up the results of the tests on these special sections, and also to find out what stresses may be expected under some other conditions of the track, tests were also run on adjacent sections which had not been specially prepared. The ties here are mostly oak, but replacements are being made with creosoted pine with tie-plates. The relation of the location of these sections to the special test sections will be seen from Fig. 26. Sections *D* and *J* were chosen as being representative track, in ordinarily good condition, and having the usual ties and tie spacing. Sections *E, F, G, I*, and *L* were chosen as showing the results of a decayed or badly cut tie. Section *M* was at a low spot in the track. Sections *D, E, F*, and *G* were used for static tests with the loading apparatus, and Sections *D, J, I, L*, and *M* were used for tests with moving loads. Section *H*, having tie-plates, was used for static tests. Section *N*, on the freight lead, having the ordinary run of ties and cinder ballast, was used for tests with moving loads. All this track was laid with 85-lb. rail. The depths of ballast were as indicated in Table 1.

21.—Preparation of the Test Sections.—In placing the ties used for the special test sections, the old ties were removed and the new ones put in without disturbing the ballast below the bottoms of the ties. This was done by the regular section men of the Illinois Central Railroad. For each test section, the depth of ballast was determined by excavating to sub-grade, near the ends of the ties on each side of the track at two points in each rail length. The track was raised sufficiently to give the required depth of ballast under the ties, and in no case was it necessary to raise the track more than 2 in.

At the north rail length of each test section, the ties were set 22 in. from center to center. The purpose of this was to get three tie spaces for a 66-in. wheel spacing. Under the other two rail lengths of each section the ties were placed as nearly as possible according to the standard practice of the Illinois Central, which uses 18 ties to a 30-ft. rail and 20 ties to a 33-ft. rail (approximately 20-in. spacing). These ties were placed with considerable accuracy, the position that each was to occupy being marked on the rail for the guidance of the section men.

Whenever the track had been in use long enough to need it, it was tamped and put in good surface. After such resurfacing, tests were not run until sufficient time had elapsed for traffic to compact the ballast which had been disturbed; generally 10 days or 2 weeks were allowed.



LOCATION OF DEPRESSION PLUGS.

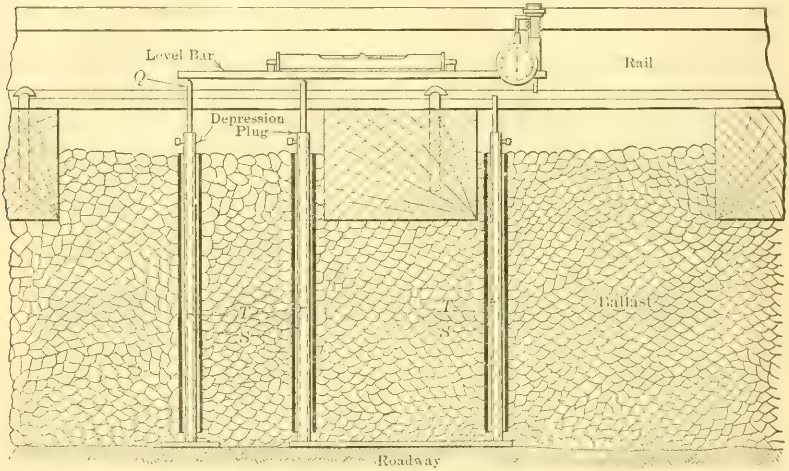
○ Single Depression Plug ●—● Double Depression Plug

●—● Strain Gauge Line

FIG. 27.

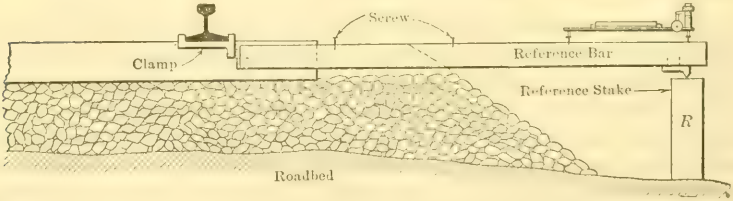
In preparing the special test sections, the depression-plugs were put in after the special ties had been placed and the track raised to its proper level. In putting in these plugs, both between and under the ties, the tie was removed and the ballast excavated down to the level of the sub-grade. The depression-plugs were then placed in the positions shown by Figs. 27 and 28, and the ballast was replaced. As this material was replaced it was carefully tamped. In placing certain of the single depression-plugs in the 24-in. ballast, a slightly different method was used. A piece of 6-in. pipe was driven with a sledge until its lower end was at the bottom of the ballast. The ballast inside the pipe was excavated, the depression-plug was put in, and the ballast was then replaced and thoroughly tamped as it was added. The pipe was then pulled up and used in placing the next depression-plug. After the depression-plugs had been in place a few days, the track was again thoroughly tamped. The track was re-tamped as often as the spot became low, until the tests were started. Although it was realized that this method of placing the depression-plugs was open to the objection that it disturbed the ballast, there was no way of placing them without doing this. As no tests were made until the depression-plugs had been in place about 2 weeks, it is thought that the ballast was fairly well compacted by that time.

After the depression-plugs were in place, the rods (*Q,* Fig. 13) were put in and adjusted for height so that the level-bar could be used from the rail to the adjacent plugs, and from these plugs to the others. On Fig. 18 the projecting upper ends of the tubes and rods of several depression-plugs can be seen.



POSITION OF DEPRESSION PLUGS

FIG. 28.



ARRANGEMENT OF APPARATUS FOR MEASURING TRACK DEPRESSION

FIG. 29.

22.—*Preparation of Test Track for Level-Bar Measurements.*—To furnish a fixed reference point from which measurements of depression could be made, a reference stake, *R,* was driven 80 in. from the rail for which the deflection was to be measured (Fig. 29). A reference bar, consisting of a piece of 2 by 4-in. lumber, was fastened at one end with a pivoting joint by a clamp to the rail, the other end resting on a knife-edge-bearing on the reference stake. Level-bar measurements were made from the reference stake to the rail, readings being taken between screws in the top of the reference bar, the outer screw being directly over the knife-edge. From the point on the rail readings were taken along the rail and from the rail to the various depression-plugs. As shown by Fig. 29, readings were taken from the reference stake to the rail and then along the rail. Additional reference stakes were placed at sufficiently close intervals to furnish a check on the depression readings.

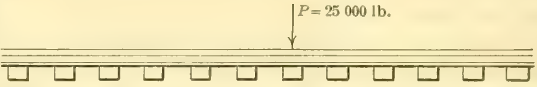
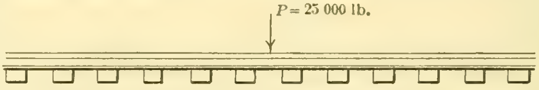
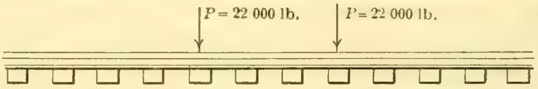
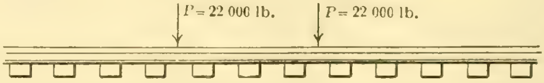
23.—Preparation for Strain-Gauge Measurements.—For a static test, preparations were made for the strain-gauge measurement of longitudinal strains in the rail by drilling gauge holes at the ends of the gauge line along which strain was to be measured. These gauge holes were on the top of the base of the rail, about ¼ in. from its edge, and, in the early tests, on only one side of the rail. These gauge lines were placed over every tie and between ties for the three rail lengths of each test section. Fig. 27 shows the typical arrangement of gauge lines for a test section of track.

It was found that the change in temperature of the rail (while in the shade when the load was in place) was sufficient to affect the strain-gauge measurements appreciably. In order to determine the corrections to be applied for this variation, readings were taken on a gauge line placed on a short unstressed piece of rail kept under the same conditions as the rail on which readings were being taken. In this way it was possible to make corrections for temperature.

24.—Procedure of Tests; Static-Load Tests.—For making a static-load test of track, the test party generally consisted of six men, there being three observers and three recorders. One man operated the strain gauge, one handled the level-bar along the rail, and another handled the level-bar on the depression-plugs. Each of these observers had his own recorder.

The typical procedure of the static-load tests, when the loading apparatus for one-axle and two-axle load was used, was as follows: The car, loaded with rails, was taken to the test section and carefully "spotted" so that the **H**-beams (Fig. 16) came directly over the points where the load was to be applied. The brakes of the car were then set and the engine was uncoupled and run away from the test section far enough not to affect the results. After the load-indicating jacks had been put in place, ready to apply the load, zero-load readings were taken with the strain-gauge and the level-bars. Load was then applied with the jacks, and a set of load readings were taken. The next load increment was applied and the load readings taken. After the desired number of increments of load had been applied (usually four), the load was removed and the zero-load readings were again taken. Readings on the standard gauge lines were taken at the beginning and end of each set of load and zero-load readings. To take a complete set of readings, including two sets of zero readings and four load readings, required from 1½ to 2 hours. For the one-axle load, there were a total of about 80 strain-gauge readings, 115 level-bar readings along the rail, and 90 lever-bar readings on the depression-plugs. For the two-axle load, there were about 115 strain-gauge readings, 115 level-bar readings along the rail, and 125 level-bar readings on the depression-plugs.

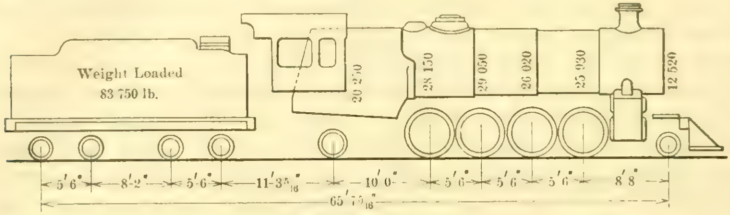
TABLE 2.—TIE REACTIONS, IN TERMS OF WHEEL LOAD, *P*. STATIC-LOAD ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.

Weight of Rail, in Pounds per Yard.	Size of Ties, in Inches.	Depth of Ballast, in Inches.	**ONE-AXLE LOAD** 											
85	6 x 8	12	.....	0.007	0.035	0.073	0.119	0.167	0.196	0.167	0.119	0.073	0.035	0.007
85	7 x 9	12	0.007	0.018	0.037	0.069	0.112	0.164	0.186	0.164	0.112	0.069	0.037	0.018
100	6 x 8	24	....	.....	0.015	0.052	0.115	0.193	0.248	0.193	0.115	0.052	0.015	....
125	6 x 8	24	.....	......	......	0.038	0.116	0.217	0.256	0.217	0.116	0.038	......	....
			ONE-AXLE LOAD 											
85	6 x 8	12	.....	0.011	0.036	0.091	0.155	0.215	0.215	0.155	0.091	0.036	0.011	....
85	7 x 9	12	.....	....	0.009	0.079	0.166	0.245	0.245	0.166	0.079	0.009	.....	....
100	6 x 9	24	......	0.011	0.038	0.082	0.152	0.216	0.216	0.152	0.082	0.038	0.011	....
125	6 x 9	24	.....	....	0.028	0.087	0.165	0.220	0.220	0.165	0.087	0.028	......	....
			TWO-AXLE LOAD 											
85	6 x 8	12	....	0.035	0.126	0.228	0.293	0.317	0.317	0.293	0.228	0.126	0.035	....
85	7 x 9	12	......	0.037	0.113	0.215	0.306	0.328	0.328	0.306	0.215	0.113	0.037	....
125	6 x 8	24	......	0.024	0.108	0.227	0.311	0.330	0.330	0.311	0.227	0.108	0.024	....
			TWO-AXLE LOAD 											
85	6 x 8	12	.....	0.070	0.162	0.271	0.332	0.332	0.332	0.271	0.162	0.070	....	......
85	7 x 9	12	0.012	0.081	0.171	0.262	0.314	0.320	0.314	0.262	0.171	0.081	0.012	......
125	6 x 9	24	......	0.013	0.157	0.281	0.342	0.352	0.342	0.281	0.157	0.043	.....	......

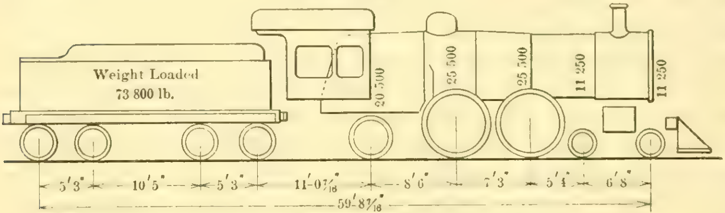
The typical procedure in static-load tests with a locomotive was practically the same as when the loading apparatus was used. Zero-load readings were taken with all instruments. The locomotive was then run on the test section and spotted at the desired point. Load readings were taken, and then the locomotive was spotted at a new position and load readings taken. After taking load readings with the locomotive at the number of points desired, the locomotive was run off the test section and zero-load readings were again taken. As it required about 1 hour to take a set of readings under the full length of the locomotive and tender, it was thought best to check up on the zero-load readings at frequent intervals, in order that errors introduced into strain-gauge results by the variations of temperature might be corrected. Hence, when readings were taken under the full length of the locomotive, generally one set of load readings was taken between the two sets of zero-load readings. Each set of readings under the full length of the locomotive and tender included about 120 strain-gauge readings, 60 level-bar readings to the rail, and 30 level-bar readings to the depression-plugs. As many of these depression-plugs were under the locomotive, the 30 readings on these required about as long as the 60 readings on the rail.

25.—Procedure in Measuring Static Pressure in Ballast.—The measurement of the pressures in the ballast with the pressure-capsule generally was not made at the same time as the other tests. In measuring these pressures, the dial micrometers were placed in the ends of all the tubes of the pressure-capsules, and the dials were set to read zero. Load was applied at the desired point, either by the loading apparatus or the locomotive, and the dials were then read. As soon as the desired loads or load in the desired position had been applied and the readings taken, the load was removed, and the zero-load readings were checked to see if they returned to zero. These readings under load were reduced to unit pressures, expressed in pounds per square inch, as described later.

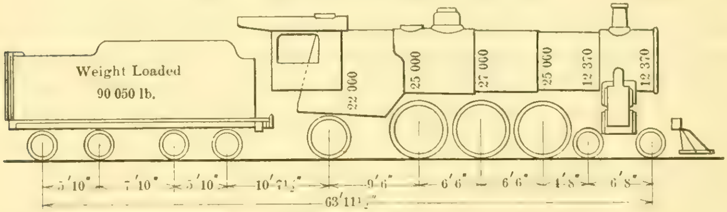
26.—Procedure of Tests; Moving-Load Tests.—Tests in which the load on the test track was produced by a locomotive running over the section are designated as moving-load tests. On the tests on the Illinois Central Railroad, three types of locomotives were used in moving-load tests, a Mikado (2–8–2), an Atlantic (4–4–2), and a Pacific (4–6–2). Fig. 30 gives diagrams of the locomotives used, with their wheel loads. The same types were used on static-load as on moving-load tests, except that the switching locomotive was used only on static-load tests and the Pacific locomotive only on moving-load tests. In all tests with the Atlantic type, the same locomotive was used. The Pacific locomotive used in the 1916 tests was not the same as that used in those of 1915. In tests with the Mikado type, use was made of whatever Mikado locomotive was available; and, in the course of the work, tests were made with 25 of this type. In all cases except the one where the equalizer was found blocked up, the locomotives were in good working condition. The tires were in good condition, there being in no case evidence of much wear. The Mikado locomotives were used at speeds up to 35 miles per hour, that being the maximum speed permitted by the regulations of the Illinois Central Railroad. The Atlantic and Pacific locomotives were used at speeds up to 60 miles per hour, a few tests being made at speeds higher than 60 miles per hour. The distance available for acquiring speed made it difficult to attain more than 60 miles per hour.



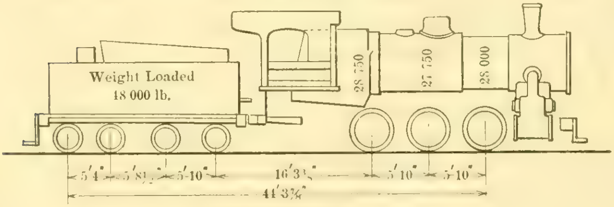
Mikado (2-8-2)



Atlantic (4-4-2)



Pacific (4-6-2)



Switching (0-6-0)

DIAGRAMS OF
FOUR TYPES OF ILLINOIS CENTRAL LOCOMOTIVES.

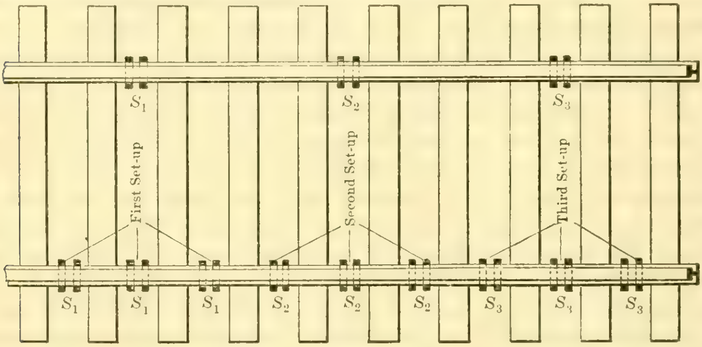
FIG. 30.

In all moving-load tests (except at very low speeds), steam was shut off as the locomotive approached the test section of the track. It was found that the tractive effort of the locomotive produced an appreciable effect on the rail stresses which was somewhat variable, and it was decided to eliminate this variable at first and to study only the effect of speed, leaving the effect of traffic for investigation later. In order to have the counterweight of the locomotive drivers in the same position in all tests, the drivers were slipped in order to cause the counterweight to come to a definite position for a given position of the locomotive on the test section. A few tests were made with the counterweight in different positions, in order to see something of the effect of change of position of counterweight. As the engineman was cautioned to start slowly and not to use the brakes severely, little trouble was experienced from the position of the counterweight changing during the tests.

For moving-load tests, the party usually consisted of three men. The procedure of a typical moving-load test was as follows: The stremmatographs were attached to the rails, and the recording devices were attached to the pressure-capsule tubes; then the drive-shaft rigging was set up and connected to the stremmatographs and to the recording pressure-capsules. The speedometer was attached to the locomotive, and, in case it was desired to measure rail deflection, the cameras for measuring deflection were set up and the electrical connections for tripping the camera shutters made. Smoked-glass disks were then put in place on the stremmatographs and on the recording pressure-capsules, the pressure of the disks against the recording needles was adjusted, and a zero-load line was drawn on the disks by rotating the drive-shaft. The locomotive was then run over the test section at the lowest speed used (5 miles per hour), and records were obtained by turning the drive-shaft by the hand-wheel. Then the locomotive was run over the test section at next to the highest speed used (25 miles per hour for the Mikado, and 50 for the Atlantic and Pacific locomotives). A run was then made at next to the lowest speed (15 miles per hour for the Mikado and 35 for the Atlantic and Pacific locomotives), and, last, a run was made at the highest speed (35 miles per hour for the Mikado, and 60 for the Atlantic and Pacific locomotives). Although this order and these speeds were not always followed, they are typical. The records for the runs at four speeds were obtained on the same glass disks. After the runs at four speeds, the smoked-glass disks were removed and examined under a microscope for evidence of error in adjustment of instruments or of dullness of recording needles. Any dull needles were replaced, necessary adjustments made, new smoked-glass disks were put in place, and another series of runs was made. After at least three good sets of records had been obtained for each instrument at a given location, the stremmatographs were moved to a new location.

In setting up the apparatus for moving-load tests, two men usually worked at attaching the four stremmatographs to the rail while the third man set up the drive apparatus and attached the speedometer to the locomotive. During the runs, one man rode on the locomotive, in order to read the speedometer and note any variations in handling or operating the locomotive. The two other men turned the drive-shaft, as the locomotive passed the section, and noted the position of the counterweight as the locomotive backed over the test section for the next run. As soon as the runs at four speeds had been made, the two men removed and examined the records and replaced the disks for the next run.

27.—Preparation for Moving-Load Tests.—Fig. 25 shows the arrangement of the apparatus as set up for the moving-load tests, and Fig. 31 is a diagram of the usual arrangement of stremmatographs. Four stremmatographs were used at one time, three on one rail between adjacent ties, and one on the other rail opposite the middle instrument of the three. At each test section the instruments were set up successively at three adjacent locations, covering a distance of eight tie spaces near the center of the rail length. Strain measurements were made along the middle of the rail, rather than near the ends, because the effect of rail joints would be appreciable near the ends, and this effect was regarded as a special problem to be studied later.



USUAL POSITION OF STREMMATOGRAPHS FOR THREE SUCCESSIVE SET-UPS

FIG. 31.

Under favorable conditions, after skill had been acquired, the necessary number of records for a given weight of rail and one condition of track, and for one type of locomotive, were obtained in from 1½ to 2 days.

28.—Tests on D., L. & W. R. R.—Tests were made on the tracks of the Delaware, Lackawanna and Western Railroad at a point near Dover, N. J., during the fall of 1916.

The section of track chosen was on the east-bound main line, about one mile east of the station at Dover. The tracks here are laid with 101-lb. D., L. & W. R. R. rails on 7 by 9-in. by 8 ft. 6-in. creosoted pine ties, tie-plates being used on every tie and screw-spikes throughout. The ballast consists of trap rock having a depth of about 18 in. under the ties. Directly beneath the ballast there are 2 ft. of cinders, which were originally used as ballast. Beneath the cinders is a light embankment of clay mixed with boulders. For purposes of the tests, the original rail at this point was replaced by new 105-lb., D., L. & W. rail section (see Fig. 107) for about ¼ mile. This change was made and the track was put in good line and surface about September 1st, a month before the tests were started.

On account of the density of traffic at the site chosen for the tests, the locomotive used was not permitted to back over the test section against traffic in returning from the runs, as was done on the Illinois Central Railroad, where the test track was within the yard limits. The test section was chosen so that this did not interfere seriously with the tests, as a cross-over at East Dover Junction and another at the Dover station, about 1½ miles apart (both operated from towers), permitted the crossing from one track to the other for the successive runs without great inconvenience or loss of time. The test section was on a light fill.

The tests were for the purpose of obtaining results on the track of a second railroad with various types of locomotives, with different ballast, a different size of ties, different rails and method of spiking, as well as different density of traffic. The wheel loads and spacing of the locomotives used are shown in Fig. 32. Tests were made with a Ten-wheel, a Mikado, and two Pacific locomotives. Of the two Pacific locomotives used, one is for passenger service and the other for fast freight service. The method of making the tests was the same as that followed on the Illinois Central Railroad, described elsewhere.

C.—Reduction of Data, and Accuracy of Instruments.

29.—Static Tests; Strain-Gauge Readings.—In static tests, the strain-gauge readings, taken on the top of the base of the rails, were reduced to stresses in the extreme fiber of the base of the rail. The general process of reduction of a strain-guage reading* involved the subtraction of the reading under load from the reading under zero-load, the correction of this difference by reference to the readings on an unstressed standard bar, and the reduction of the resulting corrected strain to a fiber stress at that point by multiplying the strain by a factor dependent on the dimensions of the instrument, the gauge length, and the modulus of elasticity for steel (which was taken as 30 000 000 lb. per sq. in.). In reducing strain-gauge readings to stress in the extreme fiber of the base of the rail, consideration must also

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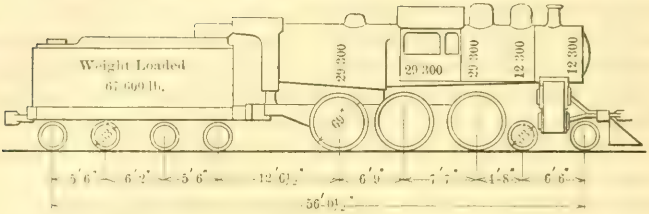
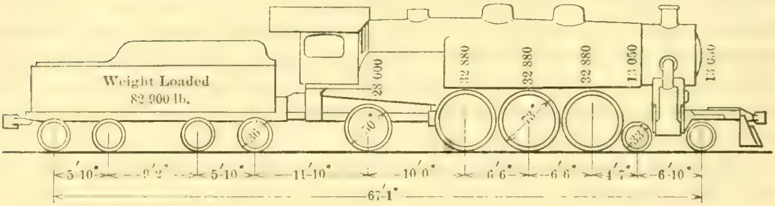
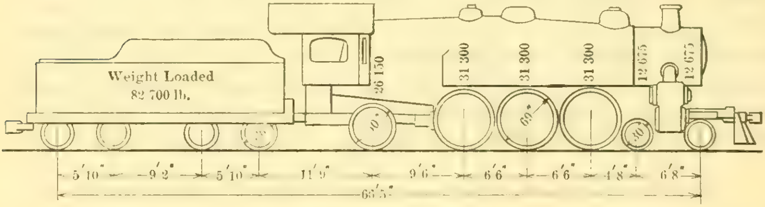
* For a detailed discussion of the method used in reducing the data see *Bulletin No. 64*, Engineering Experiment Station, University of Illinois, "Tests of Reinforced Concrete Buildings under Load," by A. N. Talbot and W. A. Slater; also, see *Proceedings*, Am. Soc. for Testing Materials, 1913, "The Use of the Strain Gauge in Testing Materials," by W. A. Slater, and H. F. Moore. The accuracy of strain-gauge readings is discussed in the latter paper.



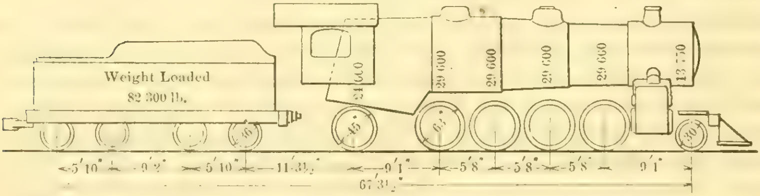
Ten-Wheel (4 6 0)



Pacific (Passenger) (4 6 2)



Pacific (Freight) (4 6 2)



Mikado (2-8 2)

DIAGRAMS OF FOUR
DELAWARE, LACKAWANNA AND WESTERN LOCOMOTIVES.

FIG. 32.

be given to the fact that the readings were not taken on the extreme fiber of the rail. This reduction was based on the assumption that the strain on a fiber varies directly as its distance from the neutral axis.

In general, with careful work, errors of observation may be kept below 750 lb. per sq. in. in stress in steel by careful handling of the strain gauge, and it is believed that the results of the strain-gauge observations came within this limit.

30.—Static Tests; Level-Bar Readings.—In reducing the level-bar readings to deflections of rail or depressions in the ballast, the first step was to find for each point the difference between the reading under zero-load and the reading under a given load. Then, beginning at the point over the reference stake (Fig. 29), these differences were added algebraically in the order in which the readings were taken. The sum of the differences up to any point is equal to the depression of the rail at that point. At the end of the section at which the readings of depressions were obtained level-bar readings were taken to a second reference point. At the second reference stake, if the differences did not sum up to zero, the variation from zero was taken as due to small cumulative errors of observation. Corrections for this error were distributed among the various readings.

As previously stated, the measurements of the depression of the sub-grade were determined by reading with the level-bar from points on the rail to the depression-plugs. Then, for any given plug, its depression with respect to the point on the rail was given by the difference between the zero-load reading and the load reading. As the actual depression of the point on the rail was known from the readings with the level-bar to the rail, the actual depression of the plug was readily obtained.

The level-bar used had a length between legs of 20 in., and the level bubble moved one division along its scale for 20 sec. change in angle of inclination of the instrument. In the field, the bar could be leveled so that the bubble came to rest not more than one division from the middle of its scale, and this corresponds to a change of elevation of one end of the bar with respect to the other of 0.002 in.

31.—Static Tests; Pressure-Capsule Readings.—The readings obtained with the pressure-capsules for static tests were in terms of movement of the pointers over the dials. These readings were reduced to unit pressures in the ballast by using calibration curves, there being a different calibration curve for each capsule.

32.—Moving-Load Tests; Stremmatograph Results.—For measuring strains from stremmatograph records, a microscope, fitted with a micrometer eye-piece and having a magnification of 75 diameters, was used. The microscopes used in measuring strains from record disks were fitted with special rotating stages, so that any portion of a record could readily be brought into the field of the microscope and the record followed by rotating the stage. The microscopes were fitted with micrometer eye-pieces. The scale of each eye-piece could be moved with an adjusting screw so that in taking a reading the zero of the scale could be placed over the image of the edge of the zero line on the record disk.

The strains were measured for points under and between wheels, and the results were tabulated on special data sheets. A test of the accuracy of reading by the microscope from the smoked-glass records was made by two observers in the early part of the tests. Forty-five determinations of stress from various records selected at random were made by each of the observers. The maximum deviation of any reading by a single observer from the average result obtained by the two observers was 0.000270 in.; the average deviation was 0.000054 in. These values correspond to variations in unit stress in the rail of 2 020 and 400 lb. per sq. in., respectively. With later experience, it is believed there are very few readings of the records in error more than 700 lb. per sq. in.

After the data had been read from the stremmatograph records, all results obtained on a given section of track by the four instruments at each speed were averaged together, the results for each side of the base of the rail being kept separate. After averaging, the mean of the stresses at the two sides of the rail was calculated, and this mean stress is the value used in plotting the diagrams and making the comparisons.

It should be noted that the values of strain measured by both the stremmatograph and the strain-gauge are the averages in the 4-in. gauge length. For points under a load, this average value may be appreciably less than the maximum value at the center of the gauge line, so a correction has been applied to obtain the maximum stress. In the static-load tests in which the strain-gauge was used, this correction was computed as follows: If f_0 is the measured stress under the load, and f_1 is the measured stress at the adjacent gauge line at a distance x (in inches) from the load, then it can be readily shown that the value to be added to f_0, in order to obtain the stress at the center of the gauge line under the load, is given by the following equation:

$$\text{Correction} = \frac{f_0 - f_1}{x - 1}$$

For the stremmatograph results, no readings at adjacent gauge lines were available for use in making this correction. From the static tests, however, it was found that this correction averaged practically 4% of the average stress under the load. Therefore, all the observed stresses under wheels in the moving-load tests were increased by 4% in order to obtain the stress at the center of the gauge line.

33.—Moving-Load Tests; Results with Recording Pressure-Capsules.—The records obtained with the recording pressure-capsules were of the same general character as those obtained with the stremmatographs. In reducing these results, readings with the microscope were taken of the values of the ordinates of the diagrams under the wheels and between the wheels of the locomotive, as was done with the stremmatograph records. By multiplying by the proper factor, these readings were reduced to movements of the plunger rods (expressed in thousandths of an inch). These quantities were then used to obtain the unit-pressure in the ballast from the calibration curves. After being computed and checked, these pressures were grouped and averaged, as was done with the stremmatograph results.

34.—Moving-Load Tests; Photographic Measurement of Depression.—The notes taken in connection with the photographic measurement of rail depression and tie depression included: description of test section, speed of locomotive, condition of light, time of day, the size of the stop (diaphragm) used, the length of exposure, the distance of the camera lens from the rail, and the position of the electric contact point for operating the shutter. The reduction of the data was made by microscope measurements of the distance between the images on the developed negative of the two positions of the reference cross-marks on the rail or on the ties. The reading of the scale in the micrometer eye-piece was reduced to inches of depression of the rail or tie by the use of a constant depending on the distance of the camera lens from the rail, the focal length of the lens, the scale value of the micrometer eye-piece, and the magnification used. From a comparison of results obtained by this method in static tests with results obtained by the use of the level-bar, measurements of deflection with the camera apparently can be made with an error of observation not greater than 0.01 in., except at high speed or on embankment subject to much vibration. The tests on the Illinois Central Railroad, however, were made on an embankment, and for that reason considerable inconsistency was found in the tests at speed.

IV.—Results of Tests.

35.—Form of Presentation.—In reporting the results of the tests, the effort has been made to present only those matters which seem to have a bearing on the fundamentals of track action and the problems of track, and to give the essential results, free as far as possible from the mass of details of the test data. When it is stated that the tests have involved the making, reading, recording, and reducing of more than 250 000 observations on rail strains alone, the need for presenting only the essentials will be apparent. Generally speaking, only averages of a considerable number of values are presented. Some use of individual results will be made in the discussion on the variation of individual values from the average value. It has been thought best to present the results largely in graphical form. This method allows general comparison to be made readily. Tabular values are also given for some of the principal results.

The results presented in this report relate principally to stresses in rail and to the depression of track as a whole. The action of the tie, the transmission of pressure through ballast and roadway, and other related matters must be reserved for a later report.

Data relating to depression of track under one-axle load, two-axle load, and locomotive loading under static conditions will first be presented, then data on stresses in rail for these loadings and for moving-load tests with locomotives; and, following these, a general discussion of the effect of speed, influence of rail section, effect of wheel spacing, condition of track, etc.

36.—Depression of Track Under Load.—Flexibility, elasticity, and stiffness are important properties of railroad track. The quality of the track is affected by variations in these properties. It is apparent even to a casual observer that track depresses under wheel loads. The weight from the wheel loads is distributed by the rail among adjacent ties, and vertical pressures are set up in ties, ballast, and roadway. The pressures transmitted by rail, ties, ballast, and roadway compress or otherwise deform these various parts of the track structure, the vertical deformation and movement of the different parts together forming the total track depression. Generally speaking, the action has the nature of elastic deformation, and, when the wheel load is removed, the track resumes its normal position, wholly or partly, according to the condition of the track and the nature and weight of the load. The stiffness and flexibility of track are dependent on the section of the rail and its flexural properties, the dimensions and spacing of the ties, and the nature, quality, and condition of the ballast and roadway.

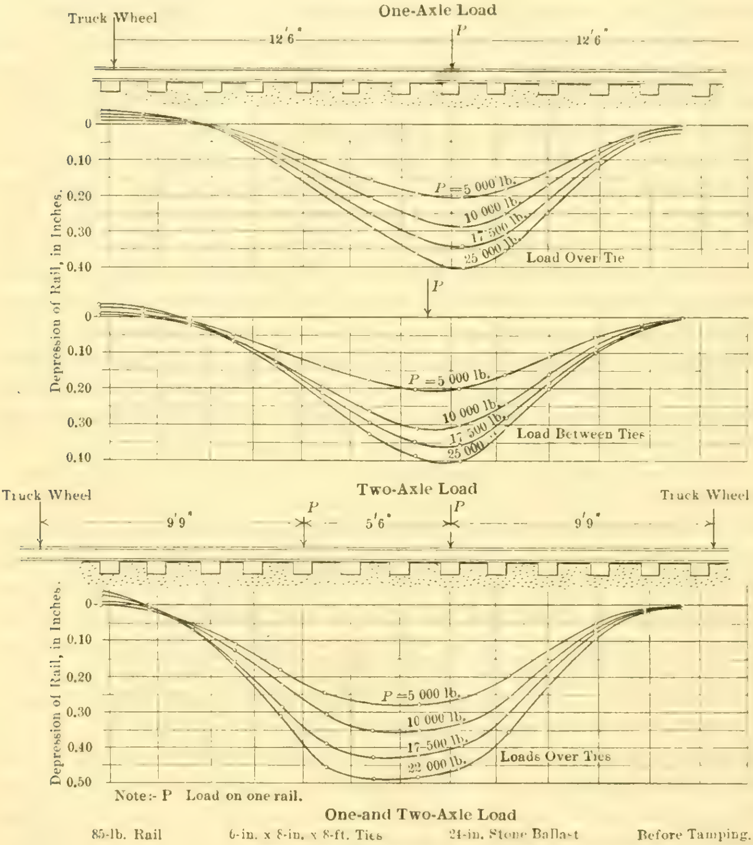
At this place no effort will be made to analyze the parts played by the rail, ties, ballast, and roadway in making up the track depression. The total depressions will be reported—the combined effect of rail, tie, ballast and roadway. At another time a discussion will be made of the relation between the deformations of the several parts of the track structure. The following general statement is given as an estimate of the division of the depressions in the various parts, in what may be called good track, under the drivers of a Mikado locomotive: compression of the tie under the rail and effect of bending of tie to bring it to full bearing on the ballast along its length, 0.05 in.; compression of 24 in. of stone ballast immediately under the rail, 0.15 in.; compression of roadway immediately under rail, 0.15 in. The bending of the rail between the ties is slight, the deflection of the rail between two adjacent ties under the weight of the driver of a Mikado locomotive on 85-lb.

rail amounting to not more than 0.01 in. in a tie spacing of 22 in. For heavier rails, the deflection, of course, will be less.

Whether the magnitude of the track depression is directly proportional to the load applied, or varies considerably from direct proportionality, is dependent on the nature of the track and its condition. For the best track in well-tamped condition (freshly surfaced), the tests indicate that the relation between the load and the resulting depression approaches direct proportionality: that is, the depression of the track is directly proportional to the load applied. For mediocre track and track which is not well kept up, it is evident from the results of the tests that the first part of the load applied produces a greater depression than a later equal additional increment of load. The effect of this on stresses in the track is important.

The foregoing refers to the relation between vertical pressures and the resulting vertical deformations or depressions at any point along the line of the rail, both at and away from the wheel load. Away from the load, the pressure of the rail on the tie will vary from tie to tie, and therefore the consequent depression will vary, but, at any point, the downward pressure of the rail and the upward pressure of the tie must, of course, be equal to each other. In the tests, the magnitude of the track depression along the rail has been measured, and the distribution of vertical pressure among the ties may be estimated from the data obtained. Records of results will be given of track depression for one-axle load, two-axle load, and locomotive loading.

37.—*Depression of Track; One-Axle Load and Two-Axle Load.*—In Figs. 33 to 41 are given track depression profiles for one-axle and two-axle loads (the axles being 66 in. apart), for tests made on the test sections of track on the Illinois Central Railroad. At the place where the tests with loading apparatus were made, the ties were 22 in. from center to center. The load was applied near the middle of the length of a rail, in order to avoid the effect of rail joints. The measurements of depression were taken on the base of the rail; the depressions reported give the vertical movement of the rail as produced by bending of rail and vertical movement of tie, ballast, and roadway. Results are given for the load applied both at a point directly over the tie and at a point between the two ties. Most of the tests are on rails of 85-lb. section, but results are also given for tests on 100-lb. and 125-lb. sections. The diagrams include tests on track having a depth of broken stone ballast below the tie of 6, 12, and 24 in. Diagrams are given for freshly-tamped track and for track which had borne traffic for a considerable time after being tamped. The results are given for the several magnitudes of load applied. It should be noted that the depression measurements were taken from the initial position which the track assumed with the loaded car on it as the basis of measurement. It will be seen that, when a load is applied through the loading apparatus, weight is released from the trucks of the car, and that the track in the vicinity of the trucks will rise accordingly. The effect of this change will appear for some distance on each side of the truck wheels, and may have some effect on the track depressions well toward the center of the car.


TRACK DEPRESSION PROFILES.
STATIC-LOAD TEST ON ILLINOIS CENTRAL RAILROAD.
WITH LOADING APPARATUS.

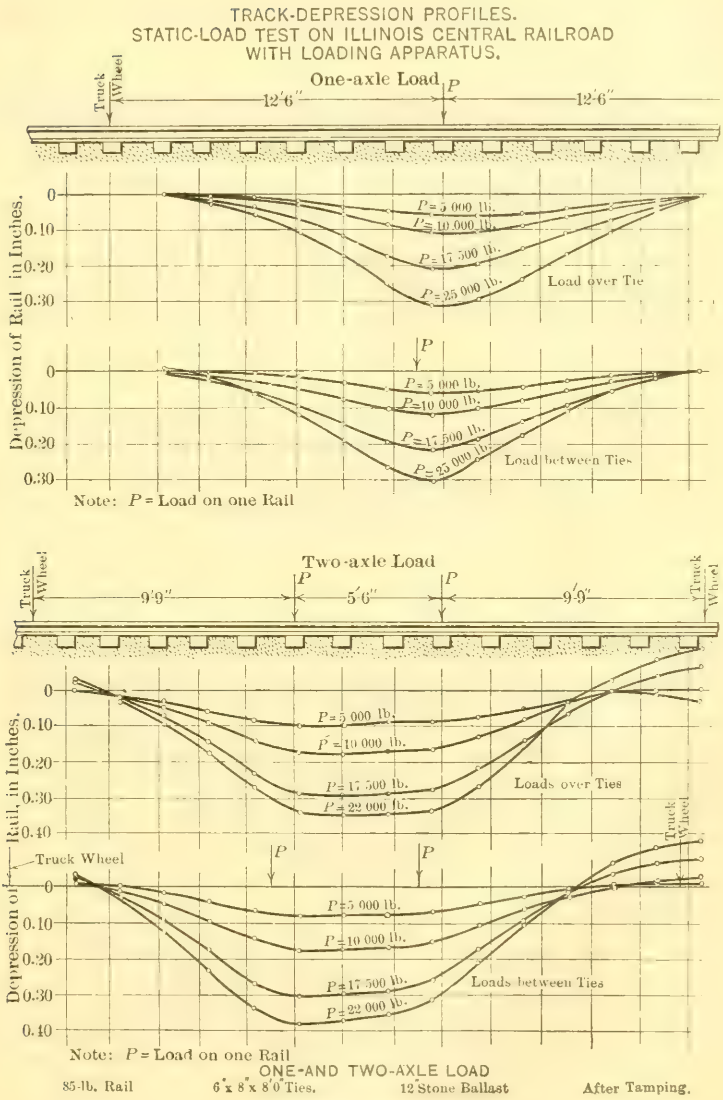
Note:- P Load on one rail.

One-and Two-Axle Load

85-lb. Rail 6-in. x 8-in. x 8-ft. Ties 24-in. Stone Ballast Before Tamping.

FIG. 33.

Figs. 42 to 45 give load-depression curves for the rail at the point of application of load in the case of one-axle load, and at a point midway between loads in the case of two-axle loads. The values plotted are from the same tests as those given in the depression profiles.



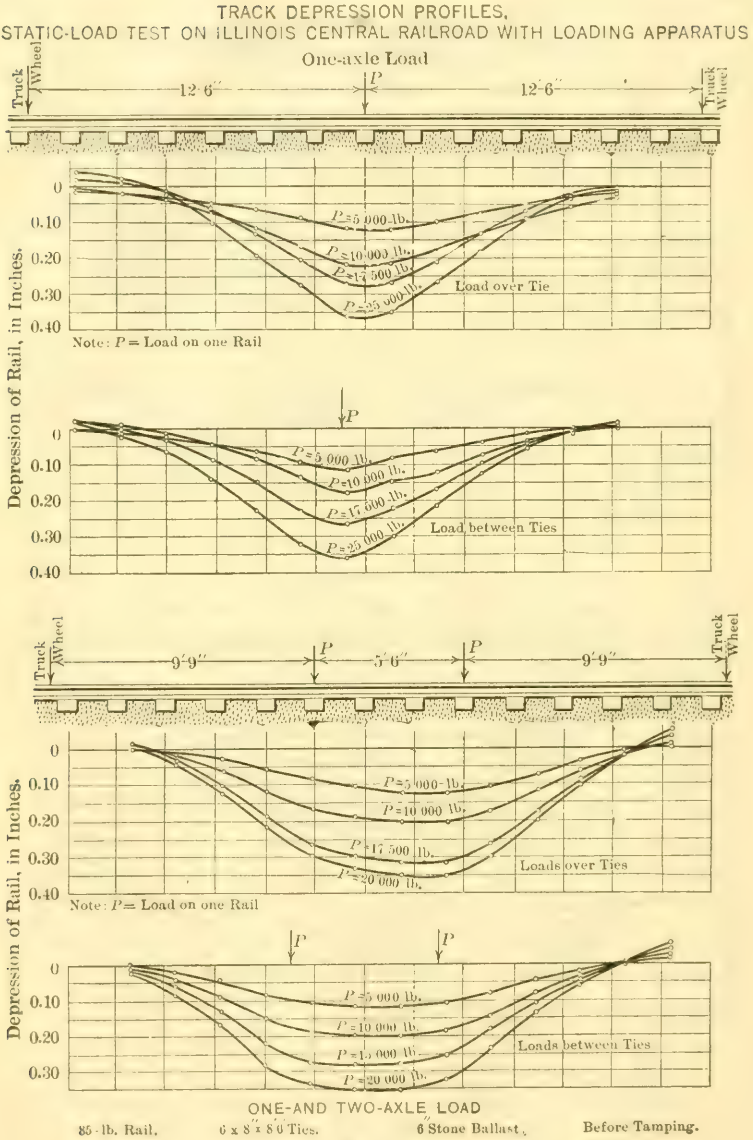
TRACK-DEPRESSION PROFILES.
STATIC-LOAD TEST ON ILLINOIS CENTRAL RAILROAD
WITH LOADING APPARATUS.

One-axle Load

Two-axle Load

ONE-AND TWO-AXLE LOAD

FIG. 34.



TRACK DEPRESSION PROFILES.
STATIC-LOAD TEST ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS

One-axle Load

Note: P = Load on one Rail

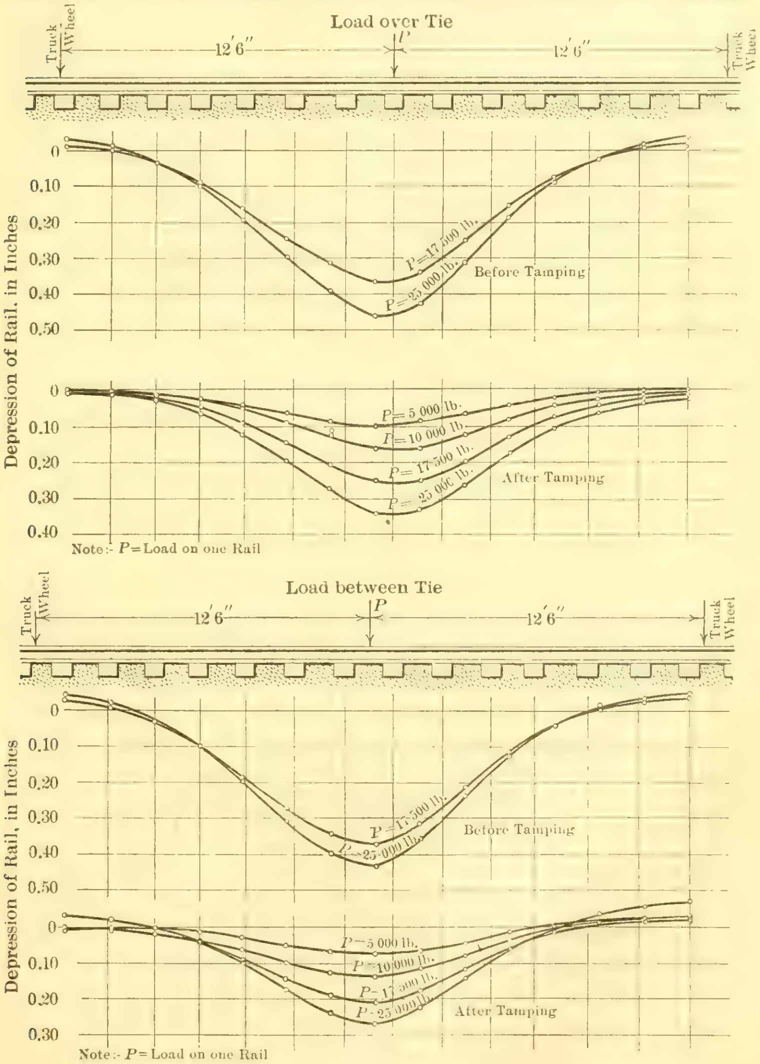
ONE-AND TWO-AXLE LOAD

85-lb. Rail. 6 x 8″ x 8′0″ Ties. 6″ Stone Ballast. Before Tamping.

FIG. 35.

TRACK DEPRESSION PROFILES.

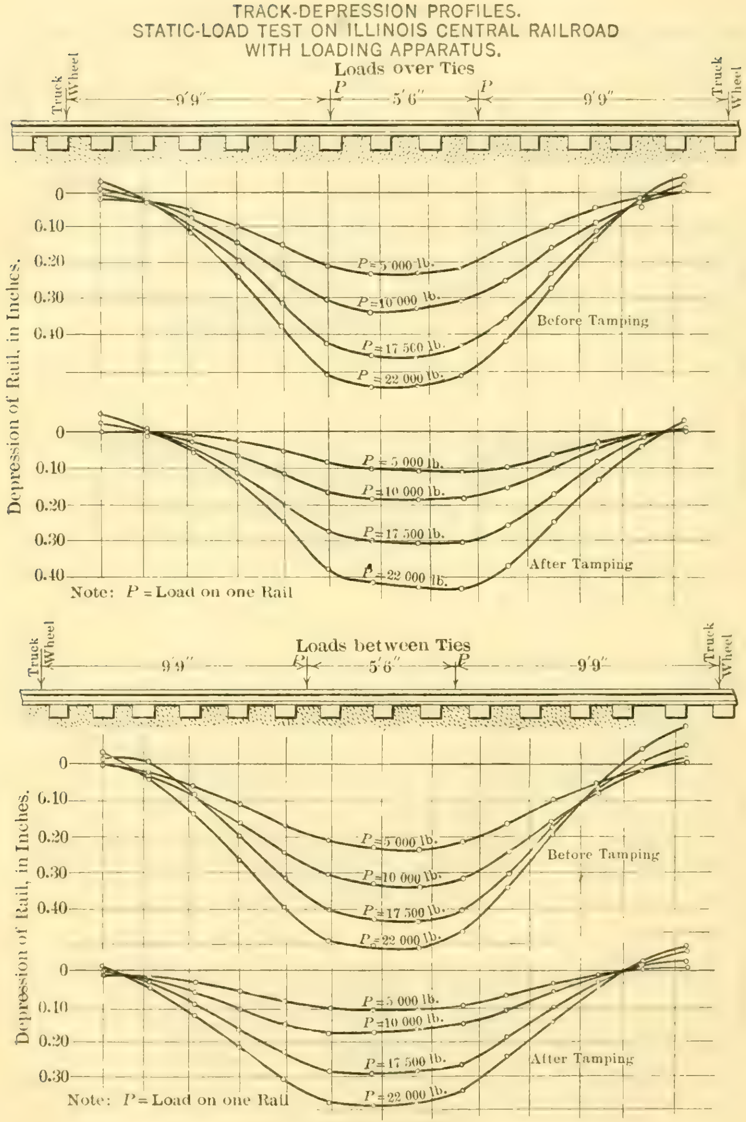
STATIC-LOAD TEST ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.



ONE-AXLE LOAD

85-lb. Rail 7″ x 9″ x 8′ 0″ Ties 12″ Stone Ballast

FIG. 36.



TWO-AXLE LOAD

85-lb. Rail 7″ x 9″ x 8′0″ Ties. 12″ Stone Ballast.

Fig. 37.

TRACK DEPRESSION PROFILES.
STATIC-LOAD TEST ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.

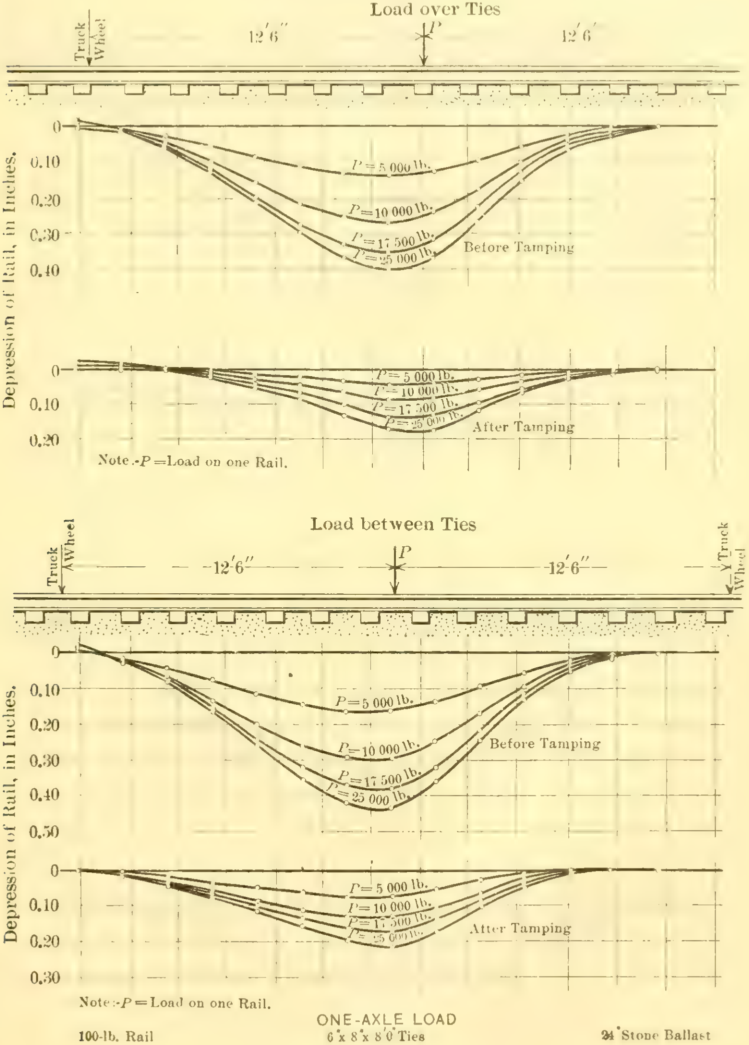
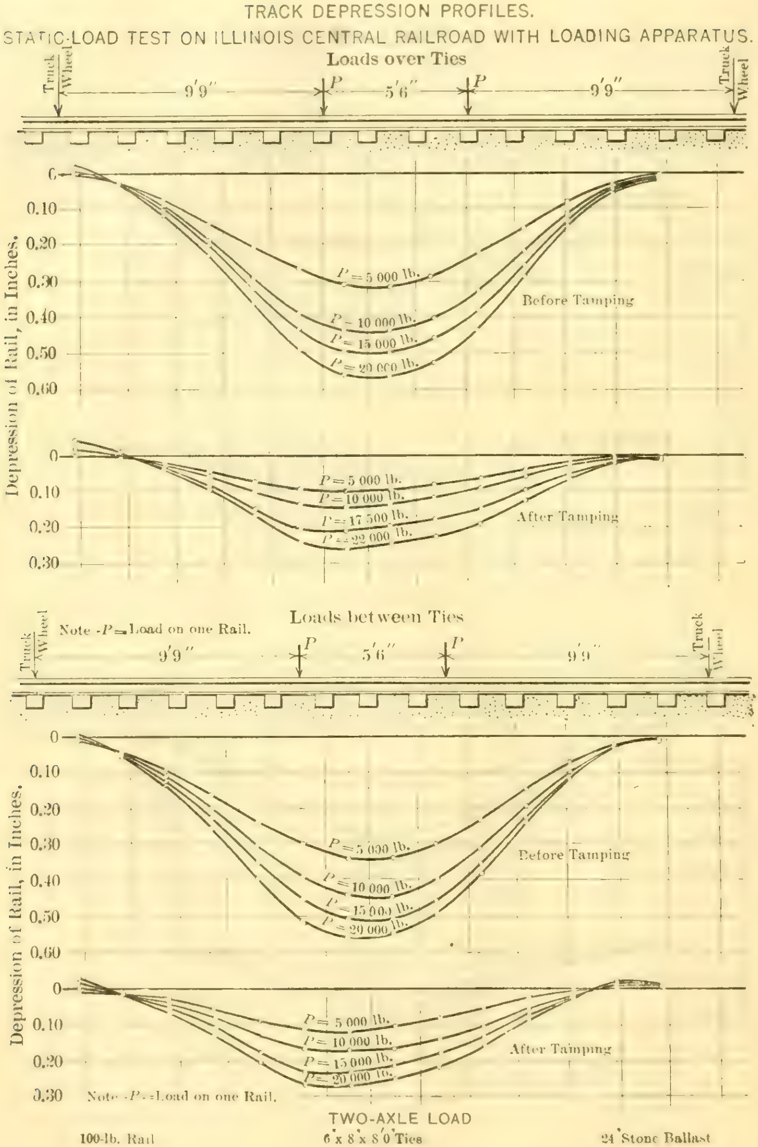


FIG. 38.

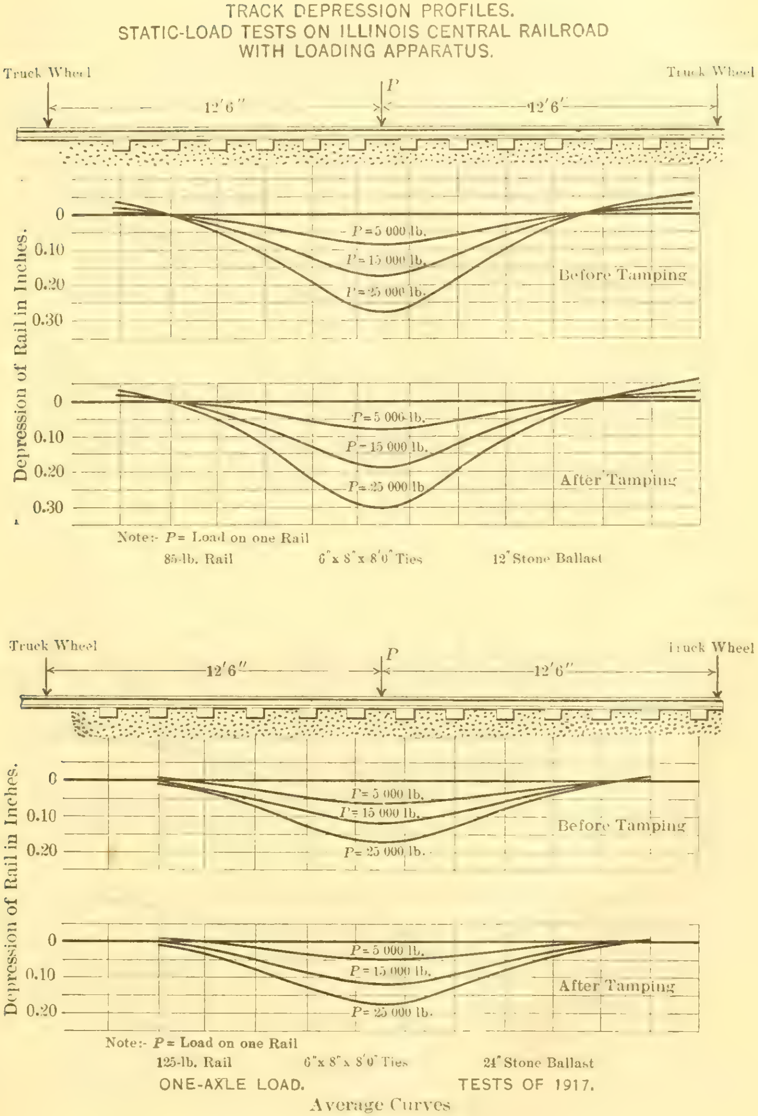

TRACK DEPRESSION PROFILES.

STATIC-LOAD TEST ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.

TWO-AXLE LOAD

100-lb. Rail 6″ x 8″ x 8′0″ Ties 24″ Stone Ballast

FIG. 39.


TRACK DEPRESSION PROFILES.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH LOADING APPARATUS.

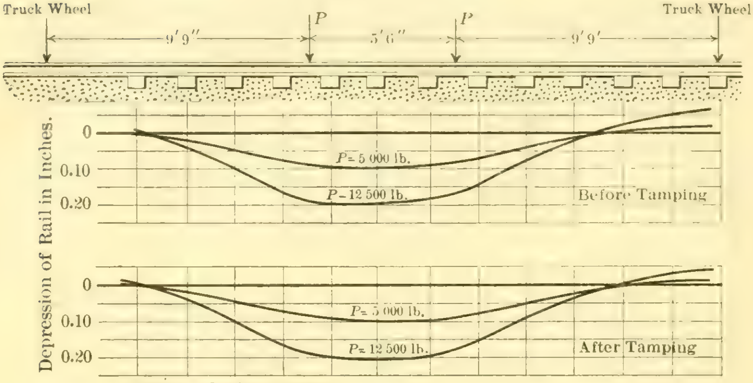
Note:- P = Load on one Rail
85-lb. Rail 6" x 8" x 8' 0" Ties 12" Stone Ballast

Note:- P = Load on one Rail
125-lb. Rail 6" x 8" x 8' 0" Ties 24" Stone Ballast

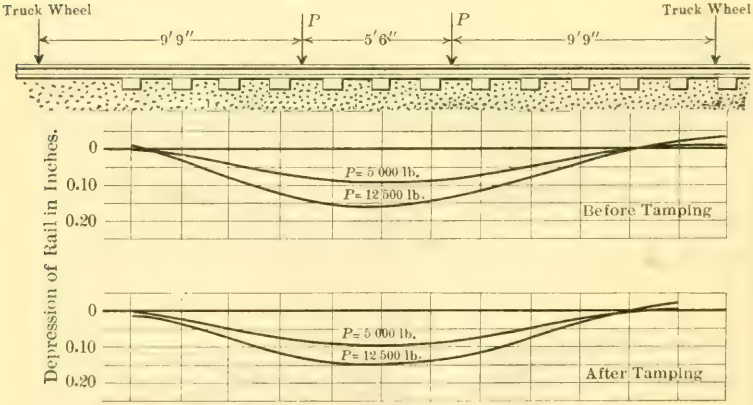
ONE-AXLE LOAD. TESTS OF 1917.
Average Curves

Fig. 40.

TRACK DEPRESSION PROFILES.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH LOADING APPARATUS.



Note:- *P* - Load on one Rail
85-lb. Rail 6″x 8″x 8′0″ Ties 12″ Stone Ballast



Note:- *P* = Load on one Rail
125-lb. Rail 6″x 8″x 8′0 Ties 24″ Stone Ballast

TWO-AXLE LOADS. TESTS OF 1917.

Average Curves

FIG. 41.

LOAD-DEPRESSION DIAGRAMS.
STATIC-LOAD TEST ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.

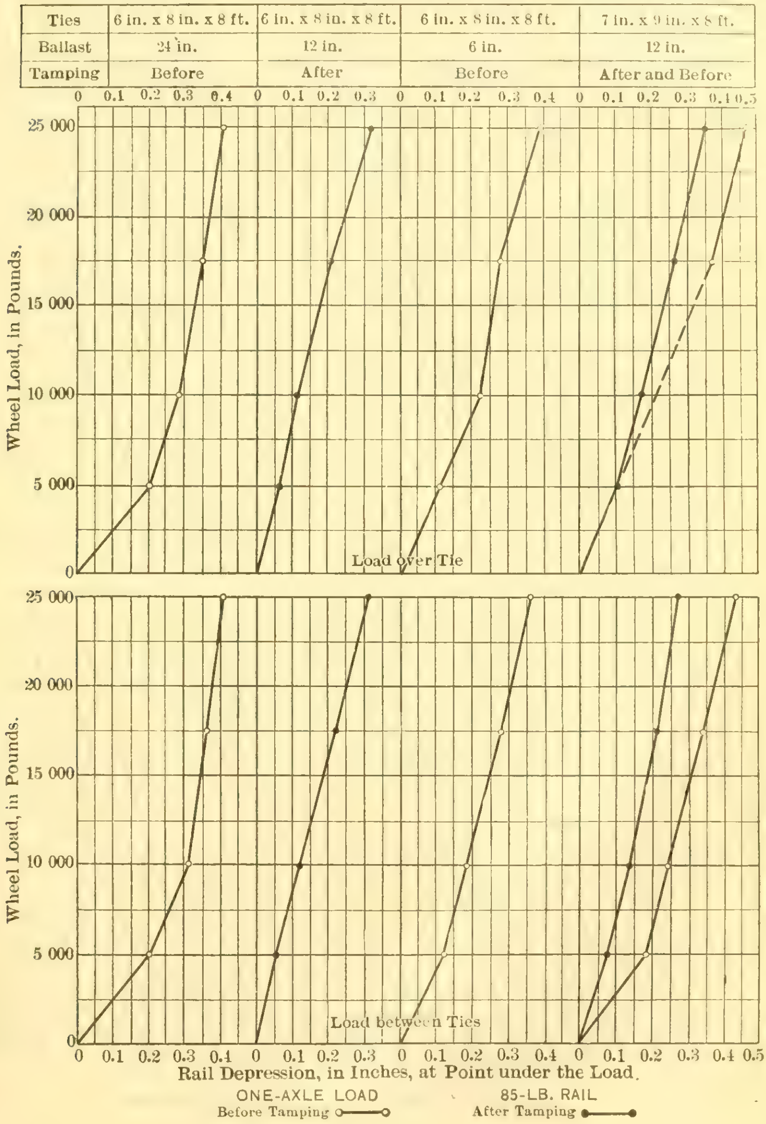
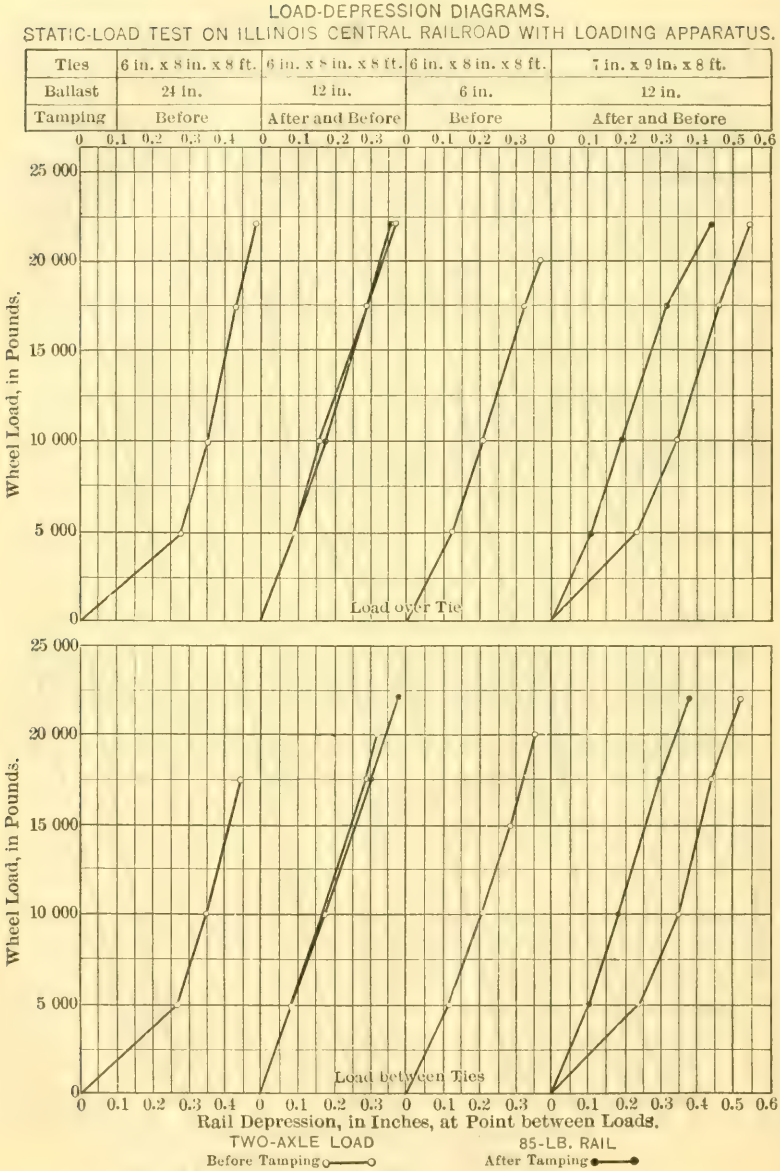


FIG. 42.



LOAD-DEPRESSION DIAGRAMS.
STATIC-LOAD TEST ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.

Ties	6 in. x 8 in. x 8 ft.	6 in. x 8 in. x 8 ft.	6 in. x 8 in. x 8 ft.	7 in. x 9 in. x 8 ft.
Ballast	24 in.	12 in.	6 in.	12 in.
Tamping	Before	After and Before	Before	After and Before

Rail Depression, in Inches, at Point between Loads.

TWO-AXLE LOAD 85-LB. RAIL

Before Tamping ○——○ After Tamping ●——●

FIG. 43.

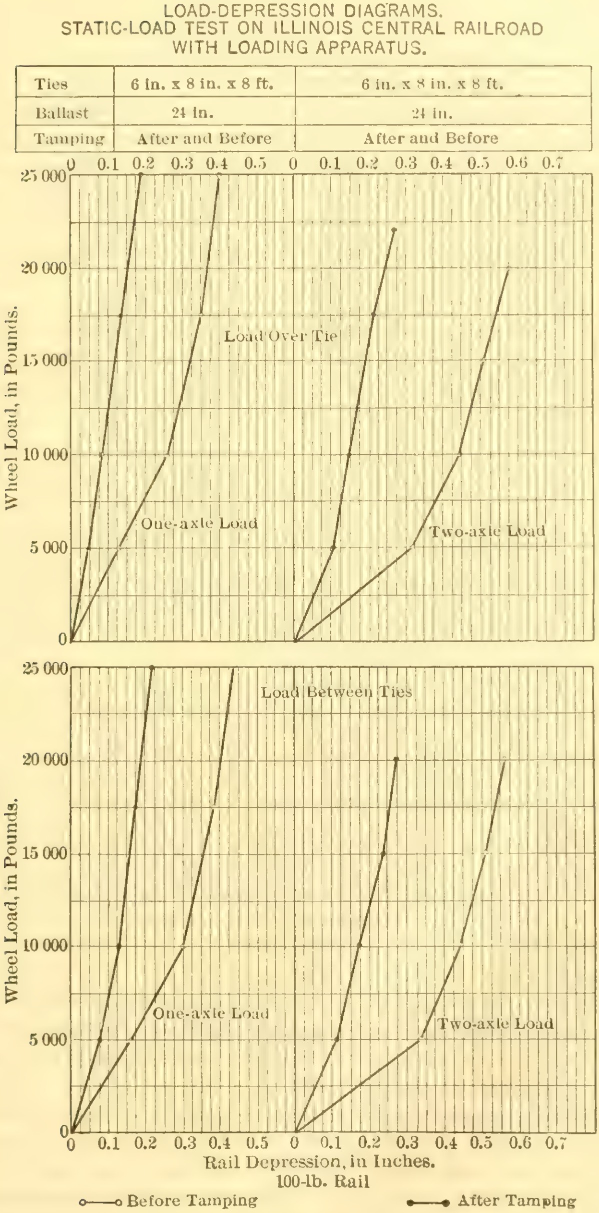

LOAD-DEPRESSION DIAGRAMS.
STATIC-LOAD TEST ON ILLINOIS CENTRAL RAILROAD
WITH LOADING APPARATUS.
Ties
6 in. x 8 in. x 8 ft.
6 in. x 8 in. x 8 ft.
Ballast
24 in.
24 in.
Tamping
After and Before
After and Before
0 0.1 0.2 0.3 0.4 0.5
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7
25 000
20 000
15 000
10 000
5 000
0
Wheel Load, in Pounds.
Load Over Tie
One-axle Load
Two-axle Load
Load Between Ties
Rail Depression, in Inches.
100-lb. Rail
Before Tamping
After Tamping

FIG. 44.

Little difference is to be found in the depression profiles for the load over a tie and for the load midway between ties. The depression is generally somewhat greater for the load over a tie. This is true for both one-axle and two-axle loads.

It is seen that there is a marked difference in the magnitude of the track depression according to the condition of the track, freshly tamped track having a smaller depression under load than track which has been subjected to the action of traffic for a considerable time after being surfaced. In this report the term "after tamping" is applied to track on which trains had been run for, say, from 1 to 2 weeks after the track had been tamped. The term "before tamping" is applied to track which had been subjected to traffic of passenger trains for, say, from 2 to 6 months. It should be stated, however, that in all these tests the track was in excellent condition.

LOAD-DEPRESSION DIAGRAMS.

STATIC-LOAD TEST ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.

Rail	85-lb.	125-lb.	85-lb.	125-lb.
Ties	6-in. x 8-in. x 8-ft.	6-in. x 8-in. x 8-ft.	6-in. x 8-in. x 8-ft.	6-in.x8-in.x8-ft.
Ballast	12-in.	24-in.	12-in.	24-in.

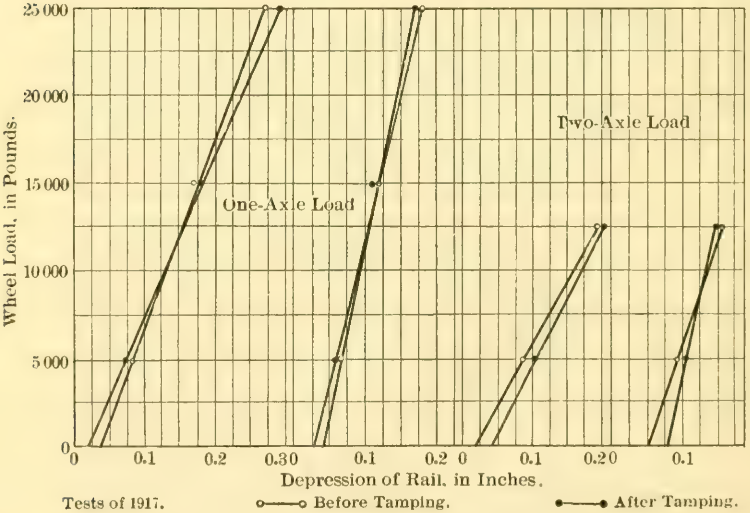


FIG. 45.

For freshly tamped track, a straight line drawn through the origin fits fairly well the several points in the load-depression curves. In other words, the magnitude of the depression of the track is directly proportional to the load applied. This property of direct proportionality in track depressions corresponds to a constant modulus of elasticity of rail-support as will be discussed under "Modulus of Elasticity of Rail-support." It will be found that the relation between the magnitude of the applied load and the magnitude of the track depression (corresponding to the quality of stiffness in properties of materials), is an important property of track, and has an influential bearing on the stresses developed in the rail under applied load.

It is apparent from the load-depression diagrams for tests marked "before tamping" that a light load produces a relatively greater depression than is given by later increments of load. It thus appears that the stiffness of the rail-support is smaller for the lighter loads. In the load-depression diagrams for condition "before tamping" a straight line may be drawn which will fit fairly well the points for the highest three loads. This line will intersect the line for zero-load at the right of the point representing zero-depression. This distance or intercept may be thought to be in the nature of play or looseness in the track. It is probably nearer correct to say that in the lower part of the diagram the track is least resistant to load (less stiff from the standpoint of elastic action) and that for the smaller loads the depression produced is not proportional to the load applied. If there is play in the test sections of track, it would seem most likely to be between the tie and the ballast immediately under the rail and adjacent thereto, so that the tie must bend before it comes to a full and even bearing along its length, and part of the resistance for the lighter loads may be that of the flexural resistance of the tie. It will be noted that a straight line drawn through the upper points of a load-depression curve for "before tamping" is approximately parallel to the corresponding line for freshly tamped track at the same location. The distance from the point of zero-depression to the point where the line above referred to crosses the line of zero-load has been found to be as much as 0.20 in. in the track tested, though it more generally runs from 0.03 to 0.10 in. in track not freshly tamped. How large this value may become in poorly conditioned track is an interesting question. The effect which the variation in stiffness of track found at the several points of the load-depression curve has on the stresses developed in the rail, on the division of pressure among the ties, and on the distribution of pressure over ballast and roadway is a matter for future consideration, as is also the effect produced by changes in the magnitude of the load itself.

The same variation from direct proportionality between track depression and load (constant modulus of elasticity of rail-support) is also shown in the depression profiles for track before tamping, in that the magnitudes of the depression for the smaller loads are greater accordingly than for the larger loads. The effect is noticeable along the rail at each side of the load.

The track depression profiles for one-axle load are of interest in showing the extent of the influence of the rail in carrying load to the near-by ties and in depressing them, the curve of flexure of the rail and the vertical movement of the ties fitting to each other. It may not be expected that the distance from the load to the point of zero-depression of rail (also point of zero-pressure on ties) can be determined accurately and definitely by tests of this nature, since the slope of the curve of flexure is very slight for some distance on each side of this point. Besides, as has already been mentioned, by the arrangement for applying the load through the jacks, an equal weight was released from the trucks of the car, and the effect of the release of load in causing the track to rise extended some distance from the wheels of the car.

An examination of the depression profiles for the one-axle load shows that the track depression caused by a given load on a rail of heavy section is less than that found for the lighter rail section at the same load. The load-depression diagrams also show this.

It is plain that the heavier and stiffer rail will distribute the load to a greater number of ties, though the effect is not well shown by the diagrams, because of the influence of varying load on the car truck and the corresponding influence on track depression in its vicinity.

The depression profiles and the load-depression diagrams show that the maximum track depression for the two-axle load is greater than for a one-axle load with the same wheel load. For the wheel spacing used, the effect of one wheel load in contributing to tie pressures along the rail extends beyond the other wheel load. In Fig. 46 typical track depression profiles (shown by light lines) from one-axle load tests are plotted in duplicate as for axle loads 66 in. apart. These have been combined by summation into composite profiles as for two-axle loads with this wheel spacing of 66 in. (shown as dotted lines). The heavy full lines are depression profiles found from the two-axle load tests. It is seen that there is close agreement between the composite curve and the profile of the two-axle load test. Comparing the diagram for 85-lb. rail with that of a single truck, in Fig. 9, which is a composite diagram for two one-axle loads obtained from analysis, it is seen that there is fair agreement with the results obtained in the tests.

Attention is called to the fact that in the tests with two-axle loads (85-lb. rail) there is no reversal of curvature visible between the load points. For a less stiff rail, or for a greater wheel spacing than 5 ft. 6 in., reversal of curvature may be obtained. It will be noted that the 100-lb. and also the 125-lb. rail section give a smaller maximum depression than the 85-lb. rail. It should also be noted that the slope of the curve of flexure under a wheel load is less for the heavier than for the lighter rail.

Table 3 gives tie reactions, expressed as proportional parts of the wheel load. These values have been calculated from the depression profile by adding the depressions for the several ties and determining the proportion which the depression at each tie bears to their sum. The table is helpful in giving an idea of the loads which come on the several ties for both one-axle and two-axle loads. The calculations are based on tests on freshly tamped track, and assume that tie pressures are proportional to depressions. The conditions of the tests are not such as to permit conclusions to be drawn relative to the effect of stiffness of rail on the distribution of load to ties.

TRACK DEPRESSION PROFILES FROM TWO-AXLE LOAD TESTS,
AND COMPOSITE PROFILES FROM ONE-AXLE LOAD TESTS.

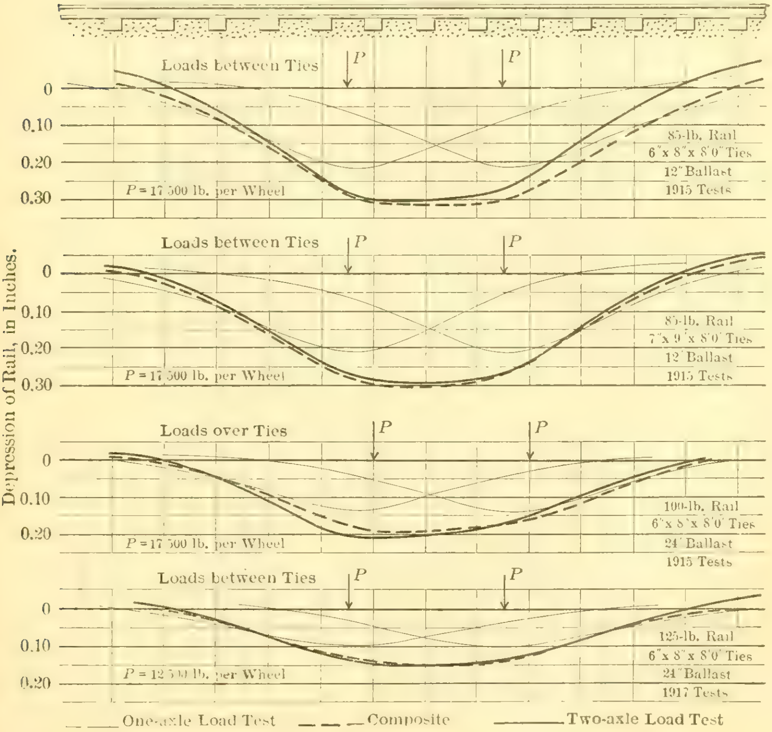
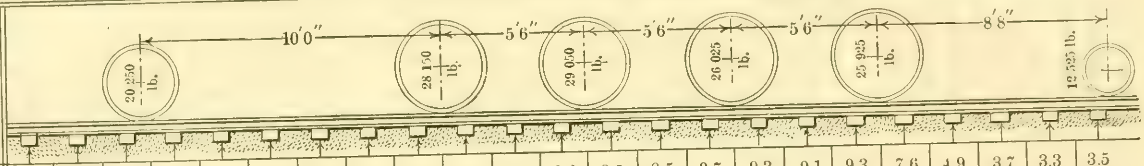


FIG. 46.

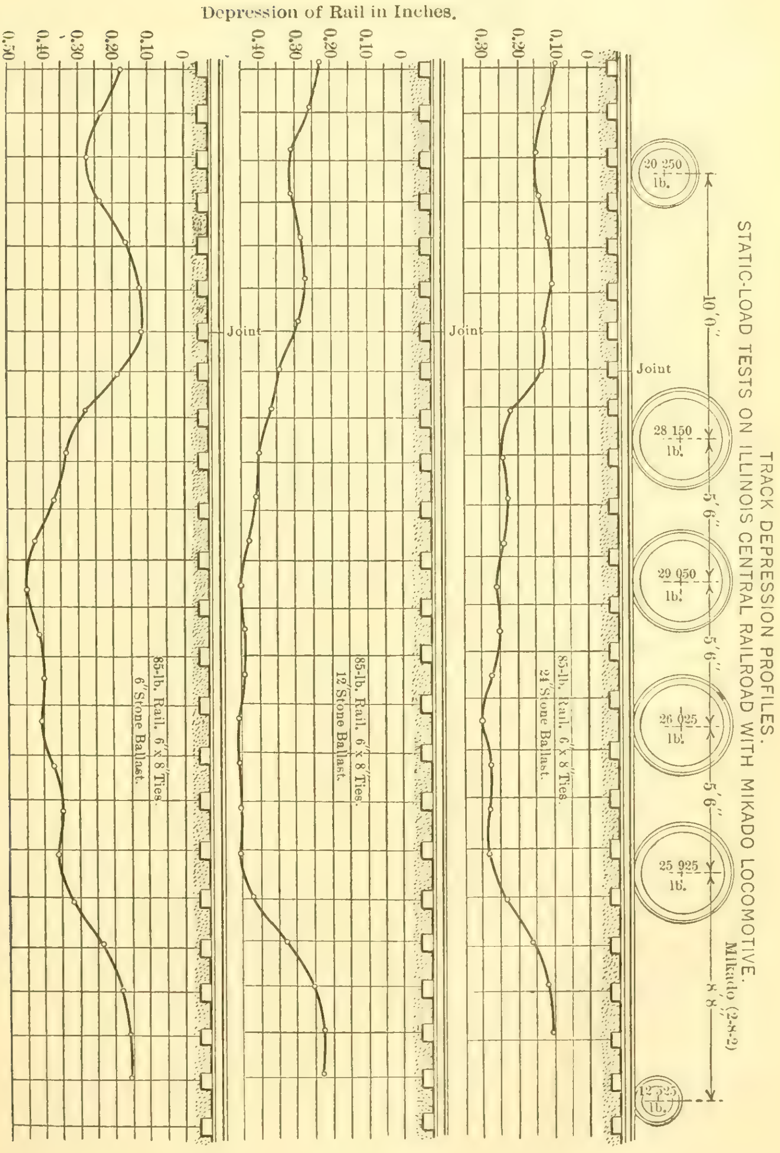
38.—Depression of Track; Static-Load Test with Mikado Locomotive.—In Figs. 47 and 48 are given track depression profiles for static loading obtained with the Mikado locomotive on 85-lb. and 100-lb. rails on the test sections of track on the Illinois Central Railroad north of Champaign. For the 85-lb. rail tests were made on three depths of ballast and two sizes of ties; for the 100-lb. rail test was made on one depth of ballast. In all these tests the track was in freshly tamped condition. It will be seen that the depression at the

TABLE 3.—Tie Reactions, in Thousands of Pounds.

Static-Load Test on Illinois Central Railroad with Mikado Locomotive.



Weight of Rail, in Pounds per Yard.	Size of Ties, in Inches	Kind of Ballast, and depth, in Inches.																						
85	6 x 8	24 Stone	3.1	4.0	4.9	4.4	3.5	3.5	3.8	4.2	6.6	7.9	7.4	8.2	8.5	8.5	9.7	9.3	9.1	9.3	7.6	4.9	3.7	3.3	3.5
85	7 x 9	12 Stone	3.5	4.5	5.7	6.0	4.3	3.5	3.4	4.5	6.4	7.0	6.7	7.1	7.8	7.8	8.3	8 8	8.4	8.3	7.5	5.6	6.5	6.0	6.5
85	6 x 8	12 Stone	3.1	4.5	5.3	5.2	4.8	4.7	5.1	5.8	6.2	6.7	7.0	7.5	7.7	7.7	7.8	7.8	7.7	7.8	7.0	5.6	4.1	3.8	4.0
85	6 x 8	6 Stone	3.9	5.2	6.0	5.2	3.5	2.7	2.6	4.0	6.5	7.4	8.2	9.6	9.6	8.9	8.8	8.5	7.5	7.8	7.1	5.1	3.9	3.4	3.3
100	6 x 8	24 Stone	—	2.5	3.9	3.4	3.1	3.4	3.6	5.1	6.6	7.5	8.3	9.1	8.9	9.6	9.2	8.4	7.2	7.1	7.1	6.6	—	—	—



TRACK DEPRESSION PROFILES.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE.

FIG. 47.

points between drivers is nearly as much as that directly under a driver. Calculations have been made to find the load carried by each tie along the wheel base, on the assumption that there is direct proportionality of tie reaction to track depression, an assumption which is not far from correct for the condition of the track at the time of the tests. The resulting tie reactions are given in Table 4.

In Fig. 48 is given a depression profile from a preliminary test on a piece of track which had not been specially prepared for the tests. Although not recently tamped, this track was apparently in good condition. The ties were partly oak and partly soft wood, and the spacing was only fairly uniform. The maximum depression is greater than that found with the specially prepared test track. Fig. 48 also gives a depression profile for track on cinder ballast about 6 in. deep below the ties. Here, again, the track had not been recently tamped, and it is not known what part of the increased depression results from play or smaller stiffness at low loads.

39.—Depression of Track; Static-Load Tests with Switching Locomotive.—Among the preliminary tests on the Illinois Central Railroad was one with a switching locomotive, shown in Fig. 30. Fig. 49 gives depression profiles for tests with this locomotive on stone-ballasted and cinder-ballasted track at the places just reported for the Mikado locomotive, and with the track in the same condition as during those tests. The effect of the absence of truck and trailer is quite marked. In Fig. 49 is also given a depression profile for this switching locomotive on a piece of branch line which is laid with old 56-lb. rail and ballasted with cinders. Attention is called to the very great track depression under the drivers. The track had not been recently tamped, and probably was not in very good condition. It should be stated that locomotives of the type used in this test are not run over this branch line.

40.—Depression of Track of the D., L. & W. R. R.—Tests were made on the Delaware, Lackawanna and Western Railroad near Dover, N. J., to determine depression of track under the trucks of a car. A light car and a loaded car of the same kind were used. Measurements were made with a level-bar. The depression profile is given in Fig. 50. Interferences by traffic prevented making the tests as complete as those on the Illinois Central Railroad. It will be seen that this track shows less depression for a given load than that of the Illinois Central Railroad.

41.—Stresses in Rail.—The stresses reported here are calculated from values of the strains measured in the top of the base of the rail for the static-load tests, and at a point below the edge of the base of the rail for the moving-load tests. As already stated, the transformation from strain to stress is made by using a modulus of elasticity of 30 000 000 lb. per sq. in. The stresses reported are those at the

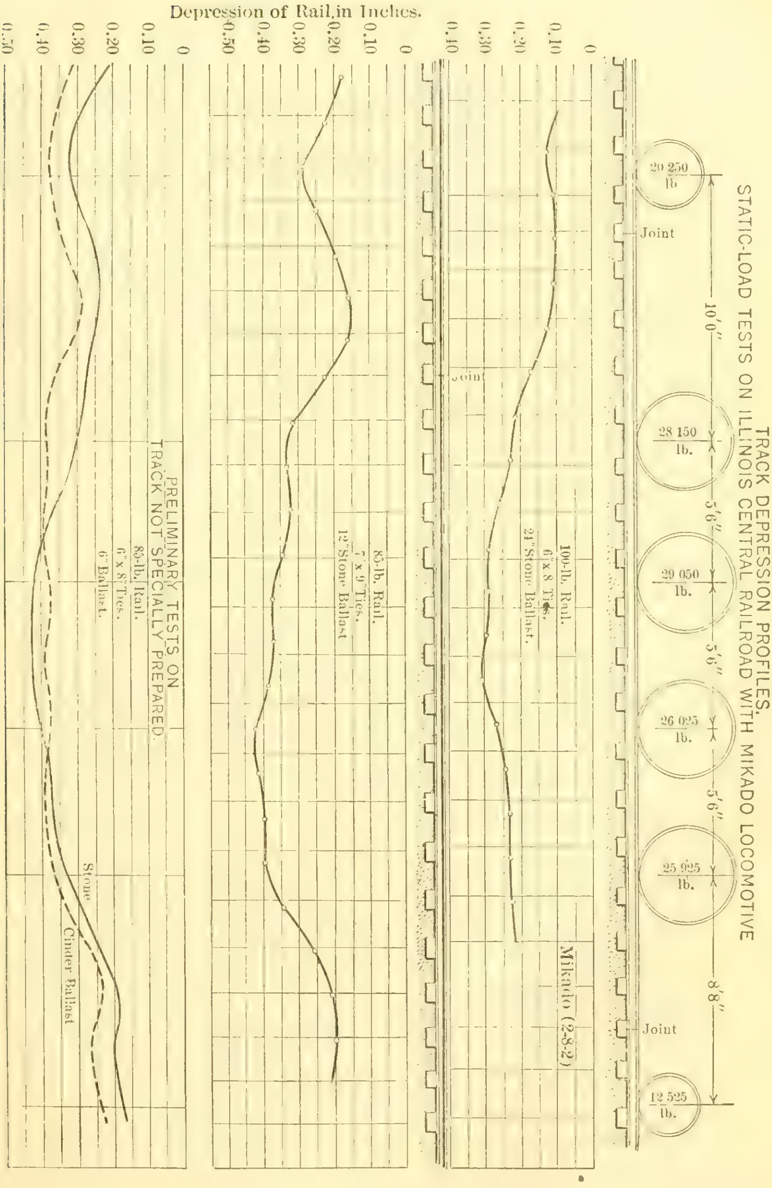

TRACK DEPRESSION PROFILES.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE
20 250 lb
28 150 lb.
29 050 lb.
26 025 lb.
25 925 lb.
12 525 lb.
10′0″
5′6″
5′6″
5′6″
8′8″
Joint
Joint
Joint
Mikado (2-8-2)
100-lb. Rail.
6″x 8″ Ties.
24″Stone Ballast.
85-lb. Rail.
7″x 9″Ties.
12″Stone Ballast
PRELIMINARY TESTS ON
TRACK NOT SPECIALLY PREPARED.
85-lb. Rail.
6″x 8″Ties.
6″Ballast.
Stone
Cinder Ballast
Depression of Rail, in Inches.
0
0.10
0.20
0.30
0.40
0
0.10
0.20
0.30
0.40
0.50
0
0.10
0.20
0.30
0.40
0.50

FIG. 48.

TABLE 4.—VALUES OF MODULUS OF ELASTICITY OF RAIL-SUPPORT.

Depth of ballast, in inches.	Size of ties, in inches.	Condition of tamping.	85-LB. RAIL.			100-LB. RAIL.			125-LB. RAIL.	
			Locomotive.	One-Axle.	Two-Axle.	Locomotive.	One-Axle.	Two-Axle.	Locomotive.	One-Axle.
24	6 by 8	Before	....	1 170	1 180	....	....	1 090	....	1 640*
			....	1 190	....	....	1 080	1 100	....	1 820*
			....	1 640	....	....	1 030	....	....	1 600
			....	....	....	....	880	....	....	....
	Average......		....	1 330	1 180	....	1 000	1 090	....	1 690
24	6 by 8	After	1 650	....	....	1 510	1 710	....	1 540	1 920
			1 660	....	....	....	1 430	....	1 420	1 840
			1 570	....	....	....	....	....	1 800	1 560
			....	....	....	....	....	....	1 830	2 010
			....	....	....	....	....	....	1 380	....
	Average......		1 630	....	....	1 510	1 570	....	1 590	1 830

Depth of ballast, in inches.	Size of ties, in inches.	85-LB. RAIL.					
		BEFORE TAMPING.			AFTER TAMPING.		
		Locomotive.	One-Axle.	Two-Axle.	Locomotive.	One-Axle.	Two-Axle.
12	6 by 8	....	880*	910*	990	810	910
		....	910*	950*	1 040	1 000	870
		....	930*	....	1 000	940	....
		....	1 270*	....	....	....	....
		....	1 210*	....	....	....	....
	Average...........		1 030	930	1 010	920	890
12	7 by 9	....	1 300	800	1 230	....	880
		....	1 500	870	1 110	1 170	980
		....	1 060	950	1 150	....	....
		....	1 190	....	....	....	....
	Average...........		1 260	870	1 160	1 170	930
6	6 by 8	....	950	970	990	....	....
		....	810	880	1 100	....	....
		....	1 280	....	1 030	....	....
		....	1 030	....	1 180	....	....
		....	1 010	....	....	....	....
	Average..........		1 020	920	1 080	....	....

* This track, marked as "before tamping," seemed to be in as good condition as "after tamping."

TRACK DEPRESSION PROFILES.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH SWITCHING LOCOMOTIVE.

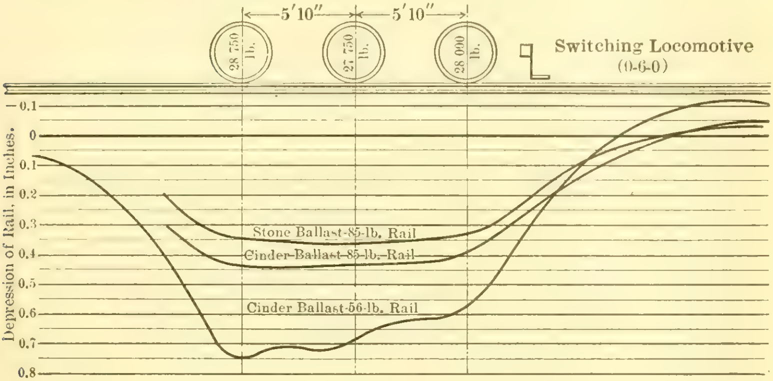
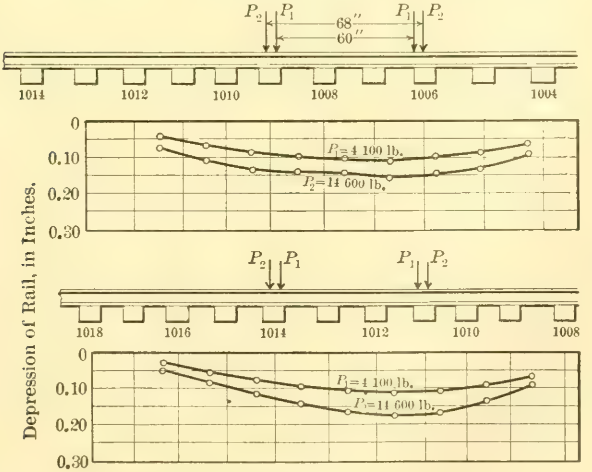


FIG. 49.

TRACK DEPRESSION PROFILES.
STATIC-LOAD TEST ON DELAWARE, LACKAWANNA
AND WESTERN RAILROAD.



Note:- P = Load on one Rail.

D.L. & W. R.R.—TWO-AXLE LOAD.

105-lb. Rail. 7″x 9″x 8′ 6″ Ties. 18″ Trap Ballast.

FIG. 50.

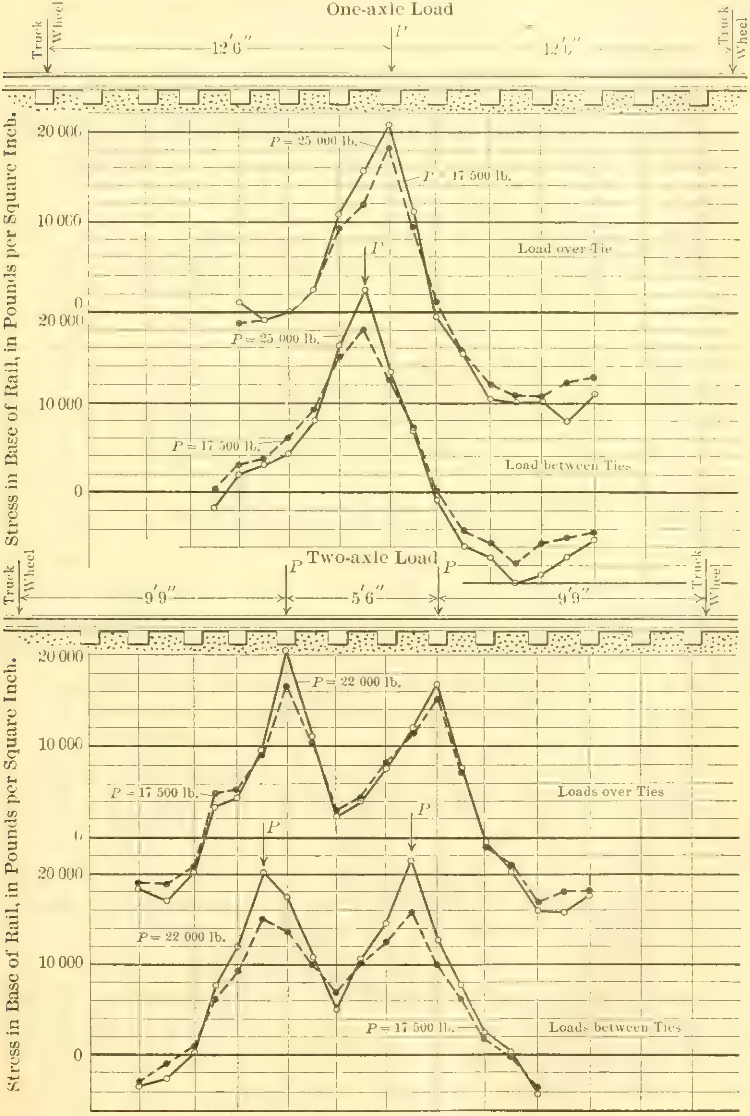
remotest fiber of base of rail, the reduction being made by assuming the neutral axis to pass horizontally through the center of gravity of the rail section. In the static-load test, the strains were measured on one side, only, of the base of rail, except in the test made in 1917, when measurements were made on both sides. Not much variation between the strains at the two edges of the base of rail is to be expected when the loads are applied by the loading apparatus. However, as will be shown later, when a locomotive is used as load, whether stationary or in motion, a considerable variation was found in the strains at the two edges of the base of rail. It should be noted that in these results no attention was given to the bearing stresses produced by the concentration of wheel load on the top of rail, nor to stresses due to lateral torsion of the rail. In general, in the moving-load tests, the stress reported is the average of many observations, and not the maximum found for an individual test. The variation of individual tests from the average will be discussed later. Although the measurements made give the total deformation in a gauge length of 4 in., and the stress corresponding to the measured strain would represent an average stress over this gauge length, the observations have been reduced, as described in Article 32 "Moving-Load Tests; Stremmatograph Results," and all the stresses given are those for a point at the middle of the 4-in. gauge length.

42.—Stresses in Rail; One-axle Load and Two-axle Load.—Figs. 51 to 59 give stress-distribution diagrams for one-axle and two-axle loads (the axles being 66 in. apart) for tests made on the test sections of track on the Illinois Central Railroad. The data were obtained at the same test sections, at the same time, and under the same conditions as the data on track depressions already given. It will be seen, also, that the release of load on the truck wheels of the car, through the application of pressure by the loading jacks, affected the stresses in rail for some distance from the wheels, and thus that the results found at points some distance from the load points may not be expected to represent accurately the stresses produced by the one-axle and two-axle loads. Measurements of strains were made with the load at a point over the tie and between ties. As previously stated, in all tests before 1917, measurements of strains were made on only one side of the rail. The results given for tests made in 1917 are averages of measurements on two sides of the rail.

Figs. 60 to 63 give load-stress diagrams for gauge lines at the point of application of load in the case of one-axle load and at the points of load in the case of two-axle loads, the average of the stresses at the two points being taken in the latter case. The values plotted are the same as those given in the stress distribution diagrams for a point under the load.

STRESS DISTRIBUTION DIAGRAMS.

STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.

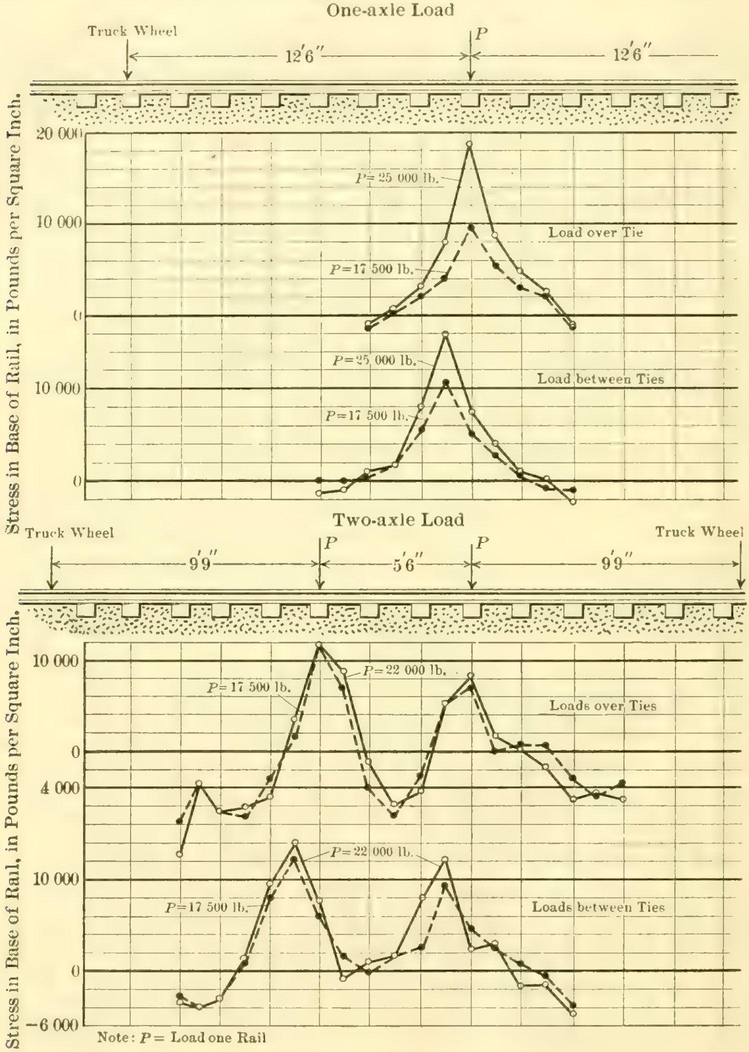


ONE-AND TWO-AXLE LOAD

85-lb. Rail. 6" x 8" x 8' Ties. 24" Stone Ballast. Before Tamping.

FIG. 51.

STRESS DISTRIBUTION DIAGRAMS.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.

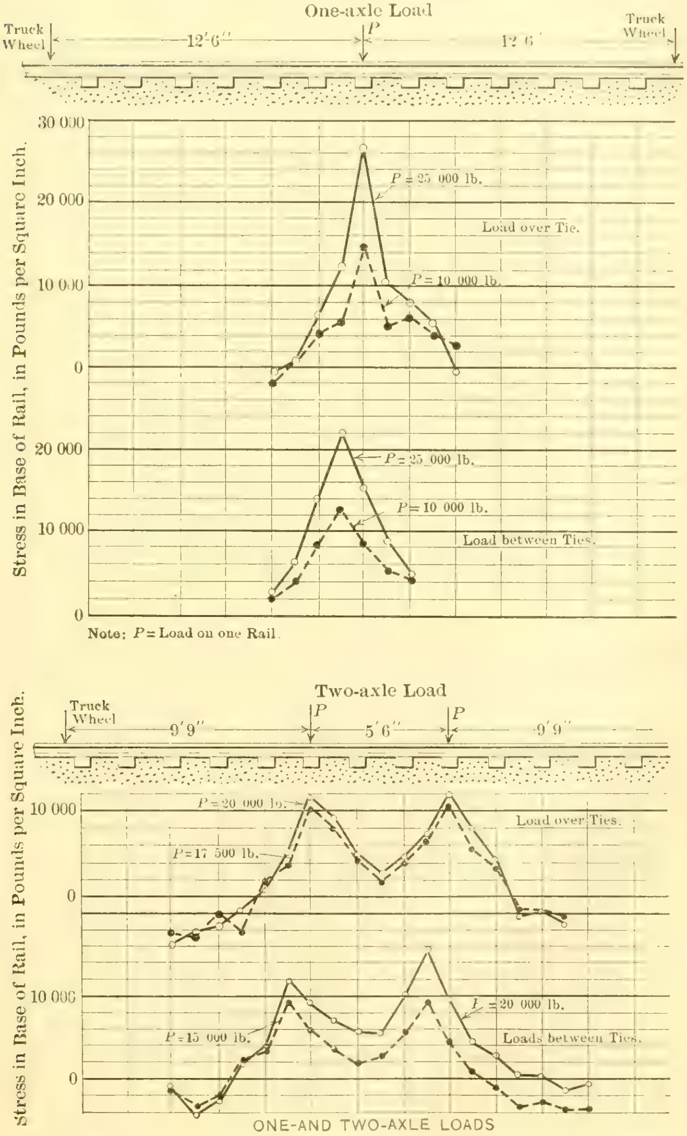


ONE-AND TWO-AXLE LOAD

6"x 8"x 8' Ties. 12" Stone Ballast. After Tamping.

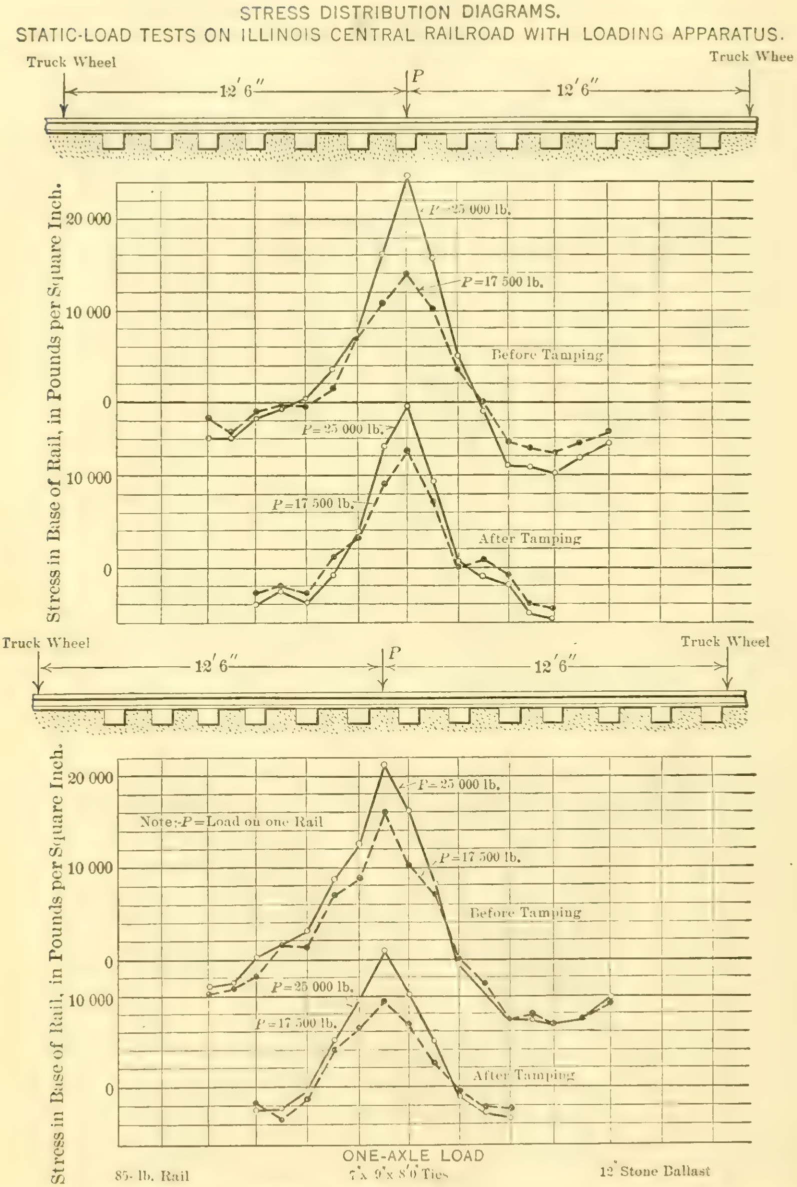
FIG. 52.

STRESS DISTRIBUTION DIAGRAMS.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH LOADING APPARATUS.



85-lb. Rail. 6″ x 8″ x 8′ 0″ Ties. 6″ Stone Ballast. Before Tamping

Fig. 53.



STRESS DISTRIBUTION DIAGRAMS.

STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.

FIG. 54.

STRESS DISTRIBUTION DIAGRAMS
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS

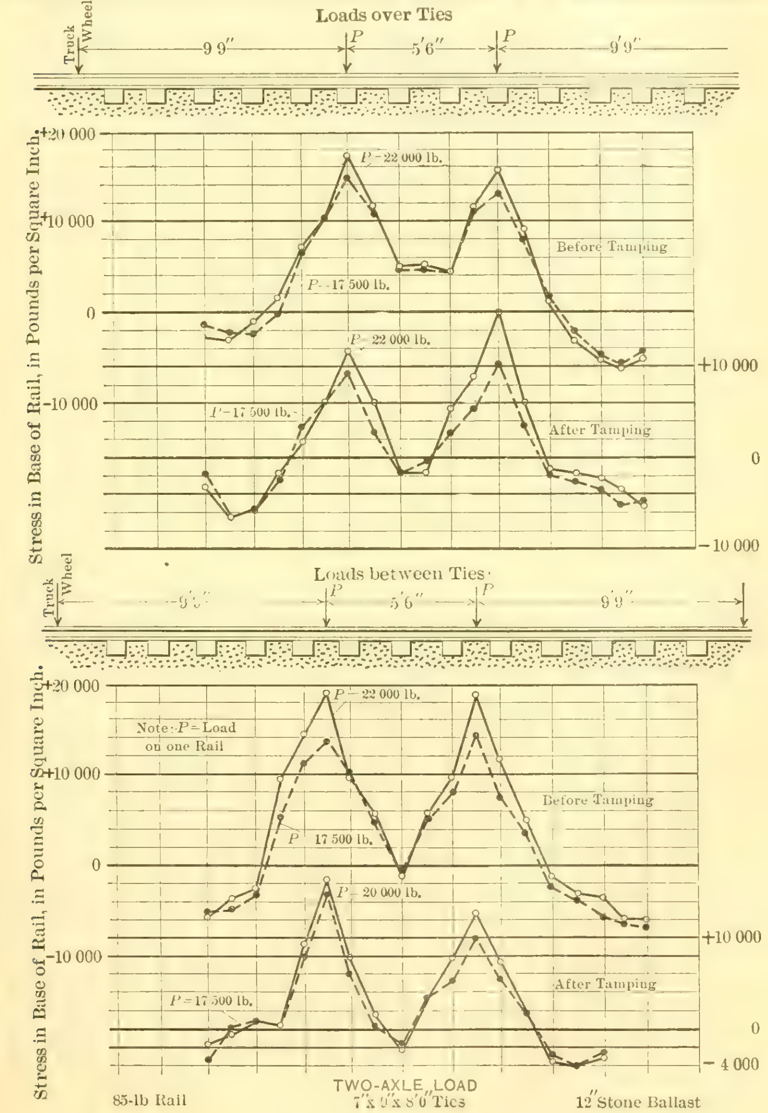


FIG. 55.

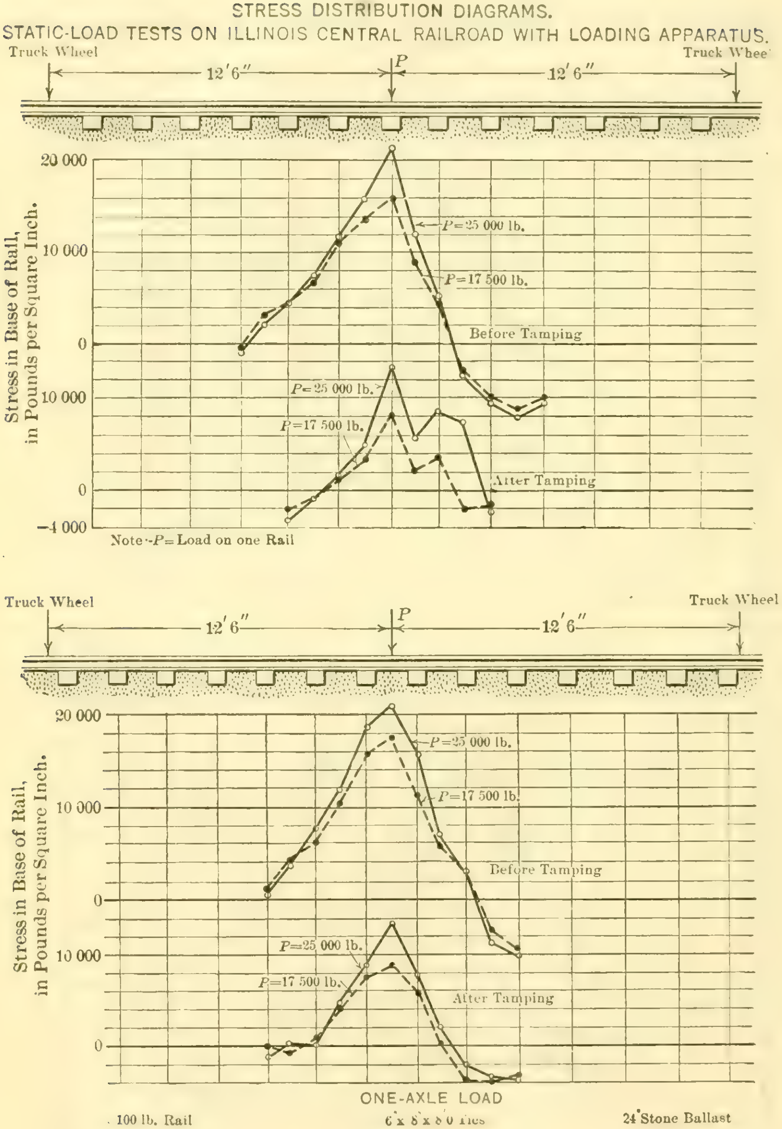

STRESS DISTRIBUTION DIAGRAMS.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.
Truck Wheel
Truck Wheel
12′ 6″
P
12′ 6″
20 000
10 000
0
10 000
0
−4 000
Stress in Base of Rail, in Pounds per Square Inch.
P=25 000 lb.
P=17 500 lb.
Before Tamping
P=25 000 lb.
P=17 500 lb.
After Tamping
Note—P=Load on one Rail
Truck Wheel
Truck Wheel
12′ 6″
P
12′ 6″
20 000
10 000
0
10 000
0
Stress in Base of Rail, in Pounds per Square Inch.
P=25 000 lb.
P=17 500 lb.
Before Tamping
P=25 000 lb.
P=17 500 lb.
After Tamping
ONE-AXLE LOAD
100 lb. Rail
6″ x 8″ x 8′ 0″ Ties
24″ Stone Ballast

FIG. 56.

STRESS DISTRIBUTION DIAGRAMS
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.

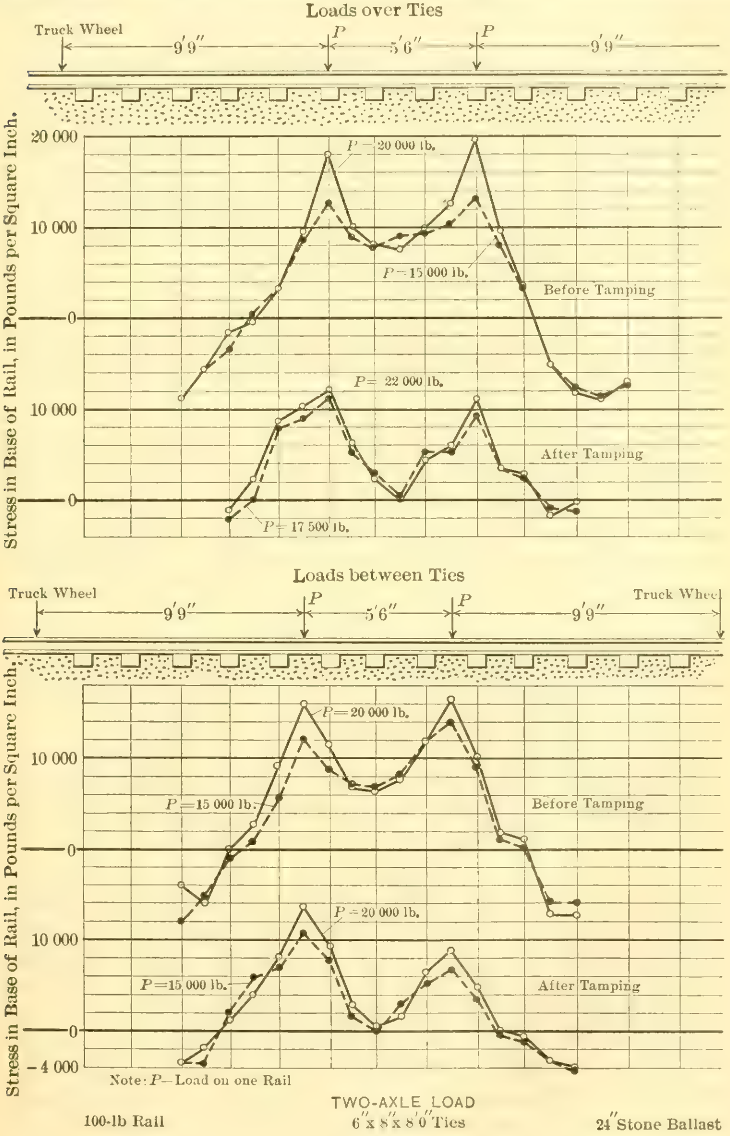


FIG. 57.

Little difference is to be found in the rail stress under the load for a load over a tie and for a load midway between ties. The stress is generally somewhat greater for the load between ties, though the difference is smaller than the variations found in different tests.

It is seen that the rail stresses differ markedly according to the condition of the track, freshly tamped track giving smaller stresses than track which has been subjected to the action of traffic for a considerable time after receiving a general surfacing. This is found to be true in tests for both the one-axle and the two-axle loads. A comparison of the stresses developed under the two conditions of track may best be made by a study of the load-stress diagrams. In general, for freshly tamped track, a straight line may be drawn which fits fairly closely the points for the several loads and passes through the origin of co-ordinates. This is the same as saying that the stress developed in the rail is directly proportional to the load applied. For track marked "before tamping" (track which it will be remembered has been described as track in excellent condition), a straight line may be drawn to fit fairly well the points for the several loads, but this line will pass to the right of the origin. For the track "before tamping", then, the stresses appear to increase proportionately to the load; but, to the stress found on this assumption must be added a constant stress in order to obtain the stress which is developed

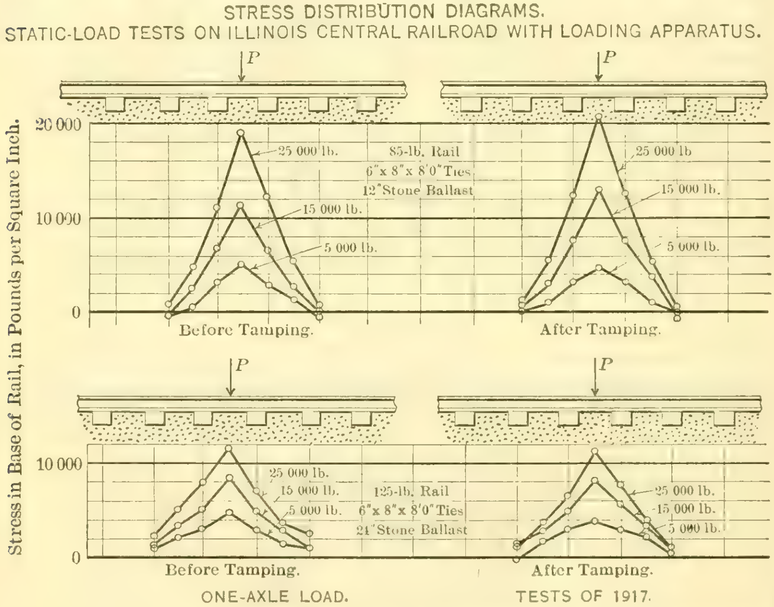
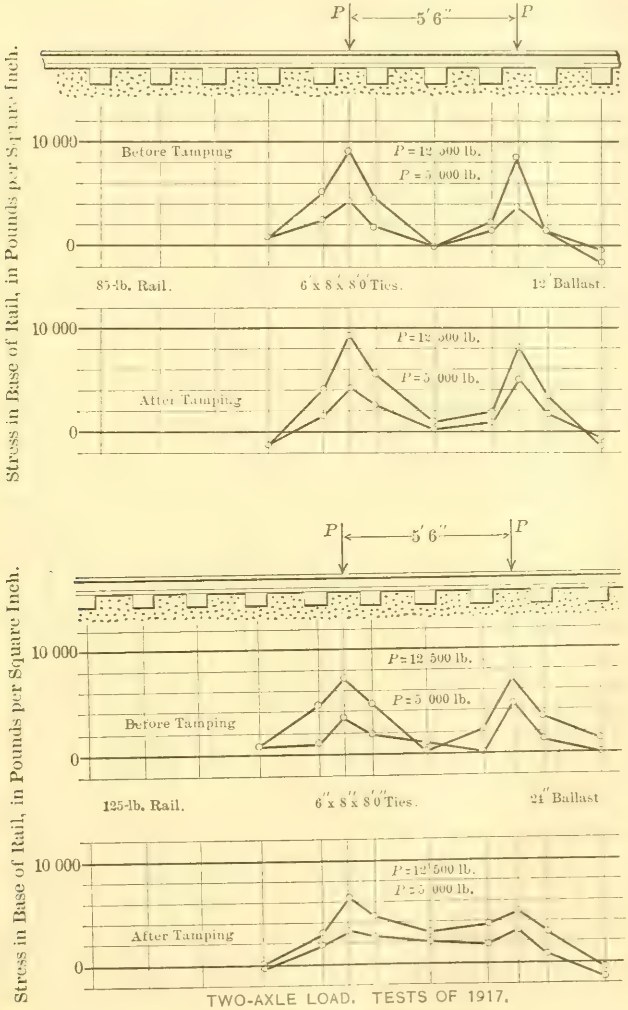


FIG. 58.

STRESS DISTRIBUTION DIAGRAMS.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH LOADING APPARATUS.



TWO-AXLE LOAD. TESTS OF 1917.
Average of Stresses on two sides of Rail.
FIG. 59.

LOAD-STRESS DIAGRAMS.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.

Ties	6 x 8 x 8 0"	6" x 8" x 8' 0"	6" x 8" x 8' 0"
Ballast.	24"	12"	6"
Tamping.	Before.	After and Before.	Before.

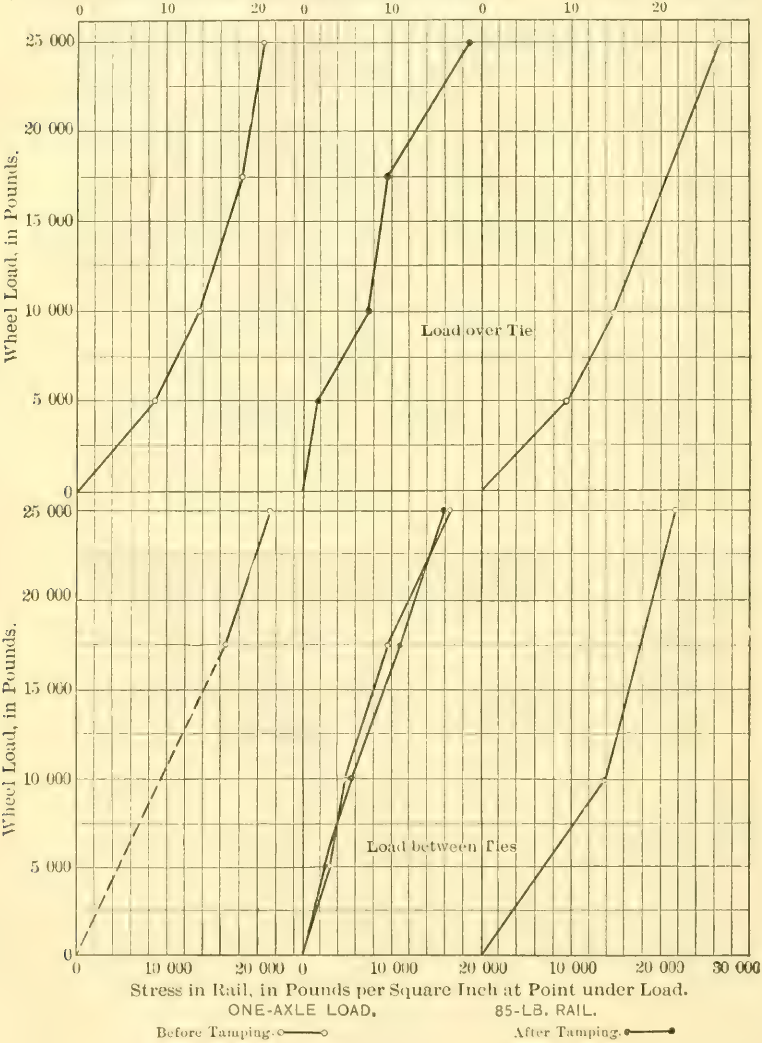


FIG. 60.

LOAD-STRESS DIAGRAMS.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.

Ties.	6"x 8"x 8'0"	6"x 8"x 8'0"	6"x 8"x 8'0"	7"x 9"x 8'0"
Ballast.	24"	12"	6"	12"
Tamping.	Before.	After and Before.	Before.	After and Before.

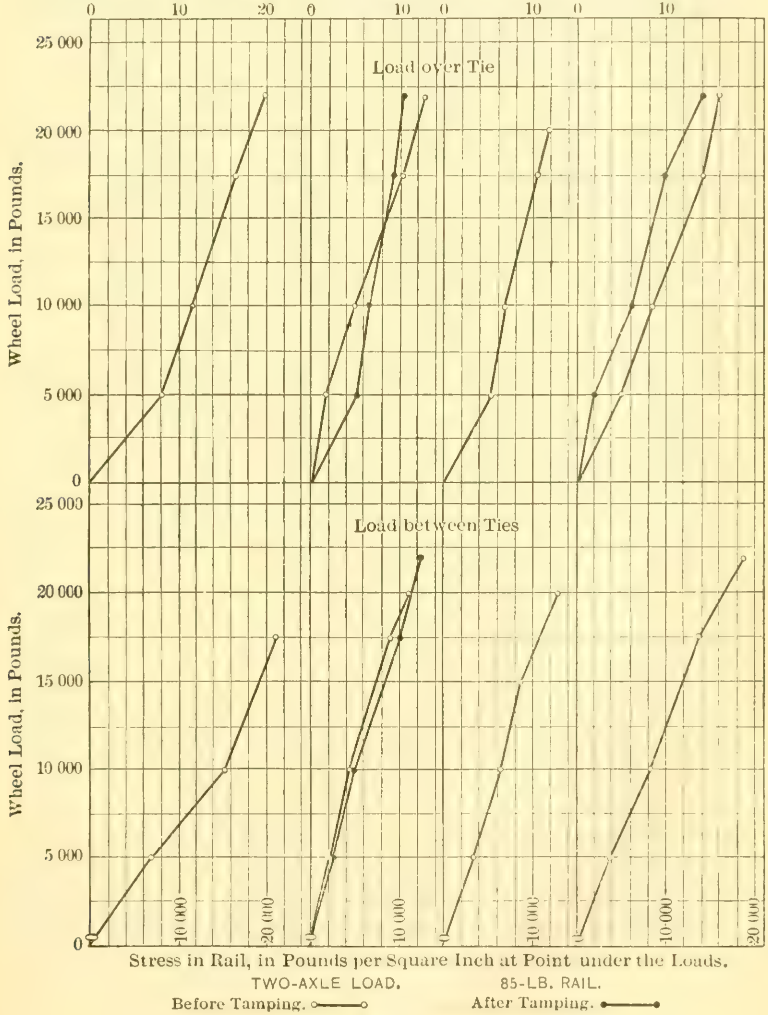


FIG. 61.

LOAD-STRESS DIAGRAMS.

STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.

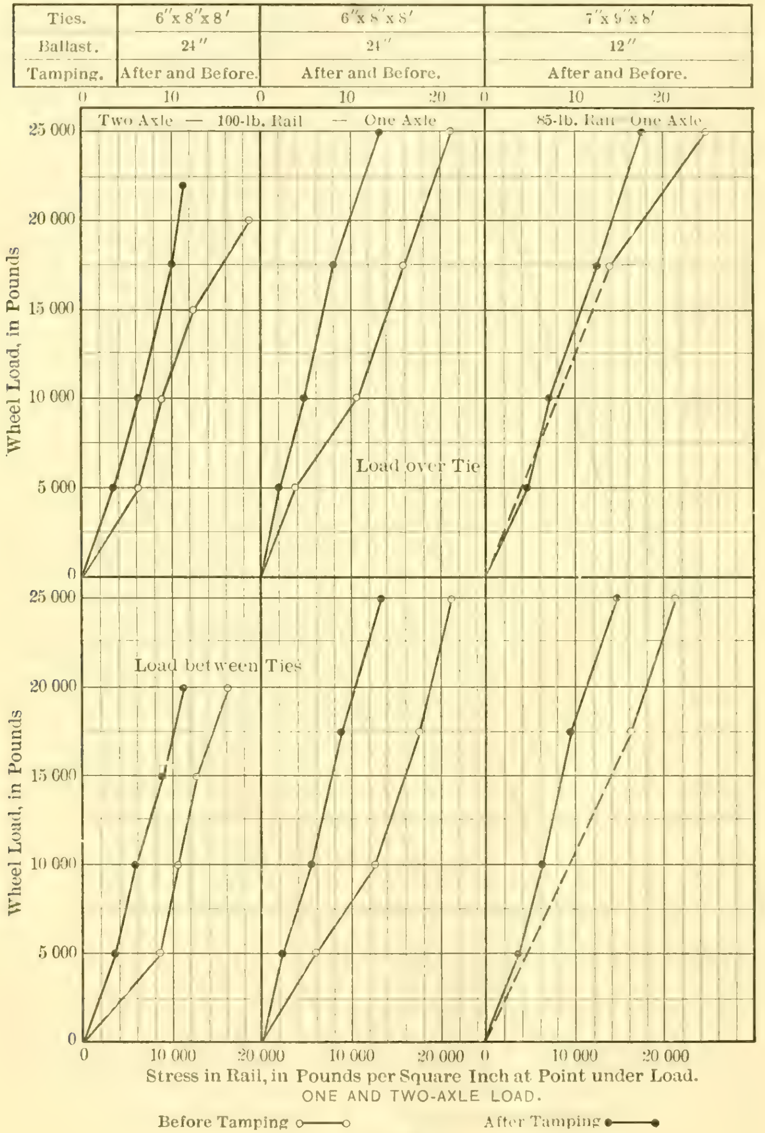


FIG. 62.

at the given load. It would appear, also, that the rate of increase of stress with increase of load is approximately the same in track "before tamping" as in freshly tamped track, the lines in the load-stress diagrams being approximately parallel for the two cases. For a rail of 85-lb. section the stress in rail in an untamped track was found to be as much as 6 000 lb. per sq. in. more than in freshly tamped track, and this was true whether the load was 10 000 or 50 000 lb. per axle, or whether the stress for the freshly tamped track was 5 000 or 20 000 lb. per sq. in. Tests have not yet been made to determine what the effect would be on track in poor condition.

LOAD-STRESS DIAGRAMS.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.

Rail.	85 lb.	125 lb.	85 lb.	125 lb.
Ties.	6″x 8″x 8′	6″x 8″x 8′	6″x 8″x 8′	6″x 8″x 8′
Ballast.	12″	24″	12″	24″

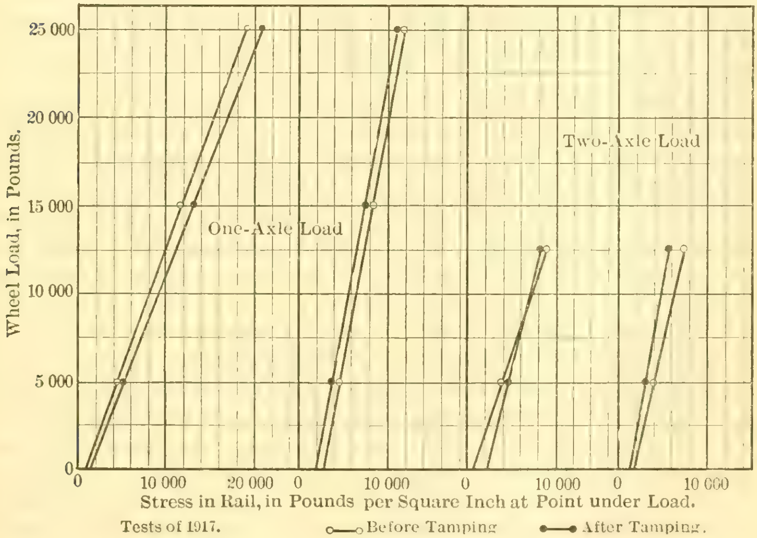


FIG. 63.

The stress-distribution diagrams give a very good indication of the way the stresses vary along the rail at points away from the wheel load, and also the way the moments change from positive to negative. It will be seen that the shape of the curves and the distribution of stresses along the rail are very similar to the distribution found by the analysis heretofore given, as illustrated in Fig. 8. In a few cases the shape of the curves at points away from the load does not accord with analytical considerations, the curvature being in the wrong direction, but this may have been due to an undetermined factor which entered into the results when the strain measurement was made on only one side of the rail.

It cannot be expected that the distance from the load point to the point of zero-stress in the rail can be determined with accuracy from the stress-distribution diagram, because the effect of the release of load on the truck wheels may extend to the point of zero-stress, and the slope of the stress-distribution curve near the point of inflection is relatively flat. Because of these facts, and because slight variations of track conditions will greatly affect the stress-distribution diagram in this vicinity, it is seen that the point of zero-stress cannot be determined accurately and definitely by tests of this nature. Although values could not be determined definitely for either, the distance from the load point to the point of zero-deformation, taken from the depression profiles, is found to be approximately three times the distance from the load point to the point of zero-deformation taken from the stress-distribution diagrams, the data for both being taken from the same tests on freshly tamped track—thus agreeing with the results found by the analysis already given.

The stress-distribution and load-stress diagrams show that, for the same wheel load, the stress in the rail under the load is less for the two-axle than for a one-axle load. It is evident that, for the load spacing used, the effect of a second load is to produce a negative moment in the rail in the vicinity of the other load point, and thus this acts to decrease the stress in the rail at each load point. To show the effect of a combination of two one-axle loads, a composite diagram has been made up in Fig. 64. The broken line represents the resultant stresses found by taking the stresses observed in a typical one-axle load test and then finding composite values by taking the algebraic sum of the stresses for two such loads 66 in. apart. It is seen that this composite line does not differ markedly from the full line which represents experimental values from tests with two-axle load. In Fig. 64 is also given, by a dotted line, a composite diagram for two-axle load obtained from the analysis outlined in Article 6, "Combination of Wheel Loads." This, also, is in agreement with the results obtained in the tests.

To bring out the fact that relations exist in the stresses and moments along the rail which vary with the spacing of the wheels and the properties of the track, there are given in Fig. 65 three composite bending moment distribution diagrams for two-axle loads which were made up by using the analysis heretofore given. The upper one (*a*) is based on a value of x_1 (the distance from a single wheel load to the point of zero bending moment in the rail) equal to two-thirds of the distance between the loads; the middle one (*b*) on a value of x_1 equal to one-half, and the lower one (*c*) on a value

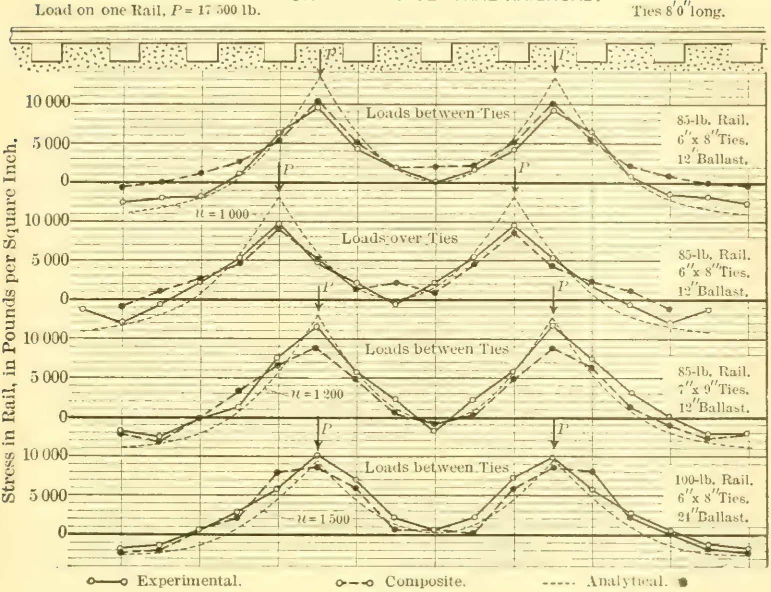

COMPOSITE STRESS DISTRIBUTION DIAGRAM
FOR TWO ONE-AXLE LOADS
FROM TESTS ON ILLINOIS CENTRAL RAILROAD.

FIG. 64.

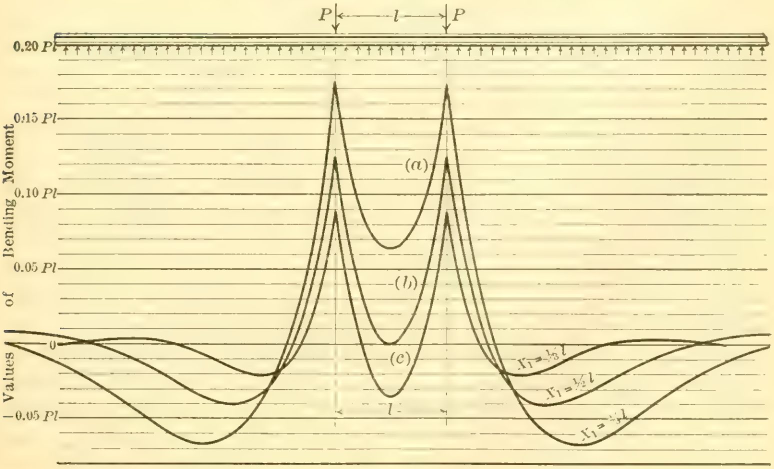

BENDING-MOMENT DIAGRAMS
FOR TWO-AXLE LOAD, DERIVED FROM ANALYSIS.

FIG. 65.

of x_1 equal to one-third, of the distance between loads. The value which may be expected to apply to track in any case will depend on (1) the spacing of the loads, (2) the rail section used, and (3) the stiffness of the rail support.

In the tests with two-axle load on 85-lb. rail the stress-distribution diagrams for freshly tamped track generally show a negative moment at a point midway between loads. The form of the diagram corresponds to the form obtained by using in the analysis a value of x_1 (the distance from a single wheel load to the point of zero bending moment) of about 28 in. For rail of 85-lb. section, in track not freshly tamped, the moment at a point midway between loads, as shown by the diagrams, runs from zero to a positive moment of 0.25 of the moment at the load point, and the stress at the load points is greater than was found with freshly tamped track. For those tests which give a moment of zero at the midway point, it appears from the load-stress diagrams that the track was in much better surface condition than for the tests which give the higher moment at the midway point. For the highest loads used in these tests, it would appear, from the stress-distribution diagrams, as if the axis of zero-stress in the diagrams for freshly tamped track had been lowered from 5 000 to 7 000 lb. per sq. in., the stress-distribution diagrams for track not in freshly tamped condition giving about the same results as this changed diagram.

For the rail of 100-lb. section, the stress-distribution diagrams for freshly tamped track show a zero moment at a point midway between loads. This form of the diagram corresponds in the analysis to a value of the distance from a single wheel load to the point of zero bending moment, x_1, of about 33 in., one-half of the distance between points of applied load. In track not freshly tamped, the moment at the point midway between loads is found to be positive and equal to about four-tenths of the moment at the wheel load, and the stress under the wheel load is greater than for track freshly tamped. For the higher loads, the same comment may be made, the diagrams for track not freshly tamped bearing a resemblance to those for freshly tamped track with the axis of zero-stress moved downward about 6 000 lb. per sq. in.

43.—Stresses in Rail; Static-Load Tests with Mikado Locomotive.—In Figs. 66 and 67 are given stress-distribution profiles for static-load tests with the Mikado locomotive on rail of 85-lb. and 100-lb. section on the test sections of track on the Illinois Central Railroad. For the 85-lb. section, tests were made on three depths of ballast and two sizes of ties; for the 100-lb. section, tests were made on one depth of ballast. In all these tests the track was in a freshly tamped condition.

STRESS DISTRIBUTION DIAGRAMS.

STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE.

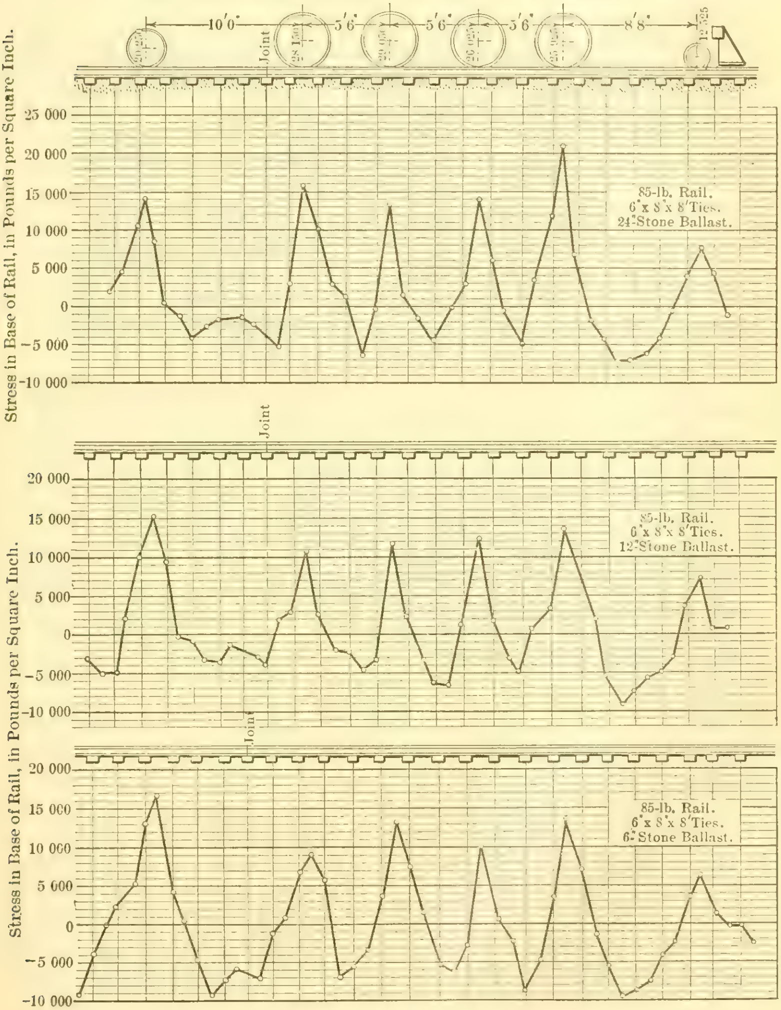
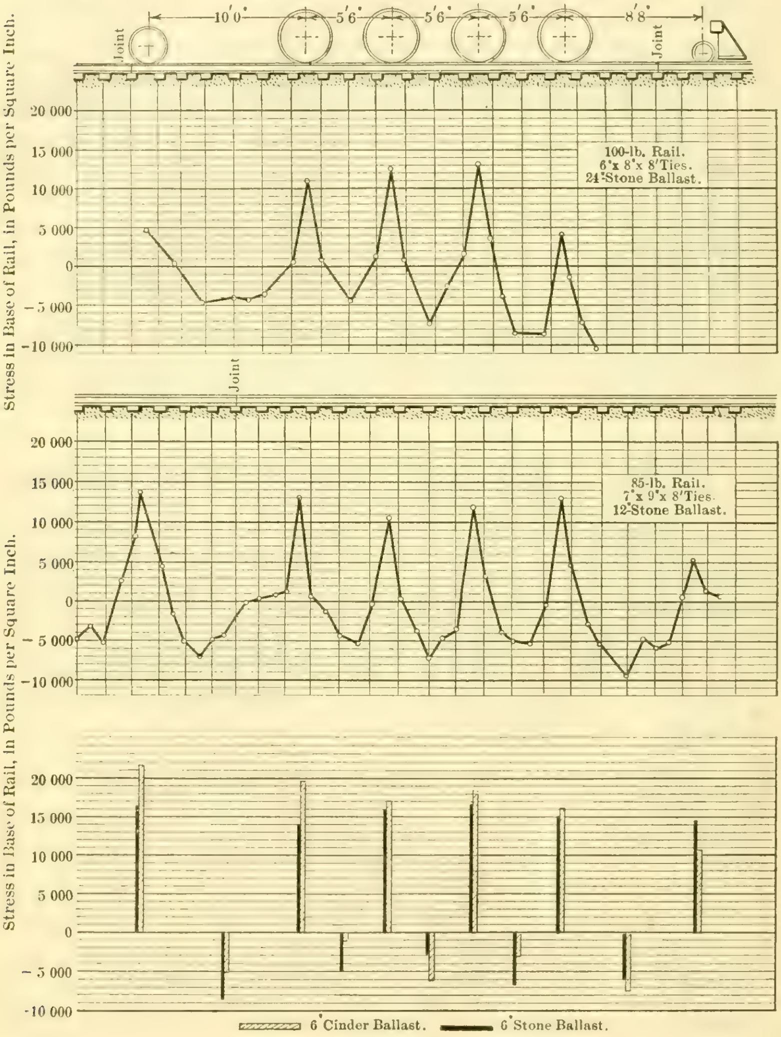


FIG. 66.

STRESS DISTRIBUTION DIAGRAMS.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE.



PRELIMINARY TEST.

FIG. 67.

The stress-distribution diagrams give a very good indication of the variation in stresses along the rail with respect to the position of the wheel loads. The maximum stresses in the rail are directly under the wheels, positive moment being developed at these points. Negative moments occur at points between the wheels. The stress under the inner two drivers is generally less than that under the outer drivers, and that under the front driver is generally somewhat greater than that under the rear driver. In the upper diagram of Fig. 67, the stress under the front driver is quite low. The values plotted on this diagram are the average of two tests at the same spot, the locomotive used in the second not being the one used in the first test. The results of the two tests are concordant. Another peculiarity of this diagram is that the stresses under the inner drivers are higher than would be expected. It will be seen that the highest negative moment in all these tests is between the front truck wheel and the front driver. The stress here ranges from 40 to 60% of that developed under the front driver. The stress under the trailer is nearly as much as that under the outer drivers, although the load on the trailer is only about three-quarters as much as that on a driver. Comparing these stress-distribution diagrams with Fig. 6, which was obtained from the analysis of track action, it is seen that the general form of the curves and the way in which the stresses vary with respect to the position of the wheel loads are quite similar.

In these static-load tests, strain measurements were made on the outer edge of the base of the rail only. In the moving-load tests, made after the static-load tests were completed, it developed that there were considerable differences between the stresses on the two sides of the rail. A static test was then made to find whether a similar condition obtained when the locomotive was stationary. These tests showed similar differences in the magnitude of the stresses on the two sides of the rail. The values found for the static-load tests with the locomotive, given in Figs. 66 and 67, then, may not be expected to represent accurately the average stress in the base of the rail. The difference between the stress on the outside of the rail and the average stress on the two sides, as will be shown later, has been found to vary in different tests. However, the results of the strain-gauge measurements on only one side of the rail are of interest and value in a number of ways, and they may be considered to show, in a general way, the distribution of stress along the rail under the given loading.

The tests on rail of 100-lb. section gave lower stresses, as might be expected, but the general distribution of stresses along the rail was much the same. The effect of the increased section of rail on the bending moment developed will be discussed later.

Fig. 67 also shows the stress-distribution diagram from a preliminary test on a piece of track with 85-lb. rail and about 6 in. of stone ballast, which had not been specially prepared for the test. This track had not been tamped recently, but was apparently in good condition. Although, as stated in Article 38, "Depression of Track; Static-Load Test with Mikado Locomotive", the track depressions were greater than for the prepared test track, it is not apparent that the rail stresses differed much from those found on the prepared test track, but there is much more variation in stress for different settings of the locomotive. Fig. 67 also gives the stress-distribution diagram for a preliminary test of track with cinder ballast about 6 in. deep and having 85-lb. rail. The stresses in the rail for this track are larger than those for track on stone ballast. The track had not been tamped recently, and it is not known what part of the increase was due to its condition.

44.—Stresses in Rail: Static-Load Tests with Switching Locomotive.—Fig. 68 gives the stress-distribution diagram for static loading with a switching locomotive, as found in an early preliminary test on the Illinois Central Railroad. The measurements are not entirely trustworthy, but both the tests on stone and on cinder ballast with 85-lb. rail give a stress under the middle driver of about 80% of that under the front driver. One stress-distribution diagram on Fig. 68 is from an early test on track on a branch line having worn 56-lb. rail and cinder ballast. The stress under the front driver is about 40 000 and that under the middle driver about 35 000 lb. per sq. in. In this test the measurements were made over a length of track of a few tie spaces, the locomotive being run forward from time to time so that each driver was successively spotted over the same gauge line. The stresses, therefore, may not be the same as though taken on the rail over the full length of the locomotive at a single setting.

45.—Stresses in Rail; Moving-Load Tests.—As has been stated in the description of the procedure of tests, in the moving-load tests, four or five runs were generally made at each of the several speeds, the locomotive not working steam while running over the test section. As shown in Fig. 31, three instruments generally were placed on one rail at points between ties and at tie spaces adjacent to each other. The fourth instrument was placed on the other rail opposite the middle one of the three instruments. As the position of the locomotive driver was always such that the counterweight of the front driver was at its lowest point when this driver passed over the middle instrument of the three, the position of the counterweight of the second or other driver when this driver passed a given instrument was different from that of the first driver when its record was made. It is seen, then, that the tests were made in such a way as to give the same effect of counterweight in each run, but that the several drivers had different positions of counterweight when passing an instrument and making a record.

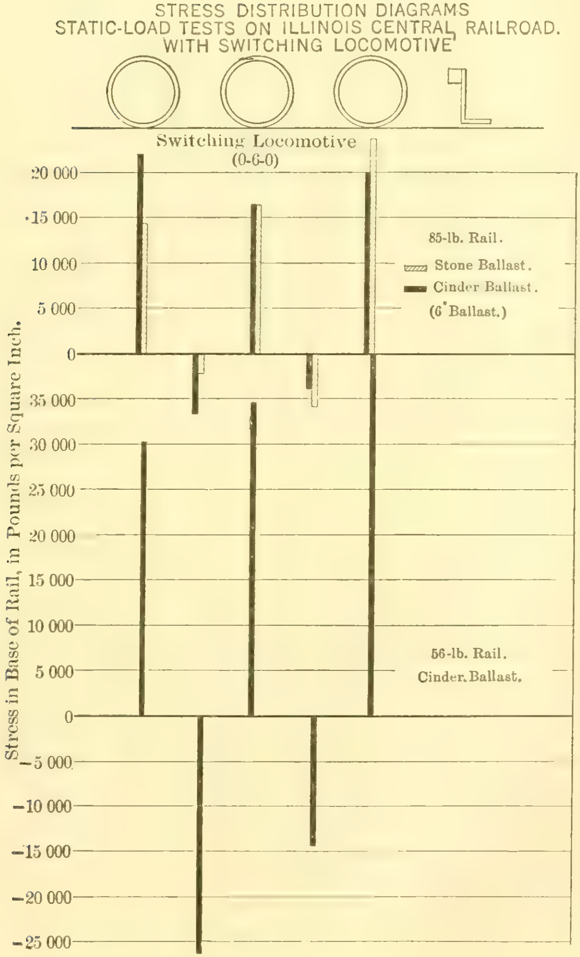

STRESS DISTRIBUTION DIAGRAMS
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD.
WITH SWITCHING LOCOMOTIVE
Switching Locomotive
(0-6-0)
20 000
15 000
10 000
5 000
0
35 000
30 000
25 000
20 000
15 000
10 000
5 000
0
−5 000
−10 000
−15 000
−20 000
−25 000
Stress in Base of Rail, in Pounds per Square Inch.
85-lb. Rail.
▨ Stone Ballast.
■ Cinder Ballast.
(6" Ballast.)
56-lb. Rail.
Cinder. Ballast.

FIG. 68.

In all the moving load tests here reported, measurement of strain was made on the two sides of the rail by each instrument, and the average stress for the two sides of the rail is here reported. In some cases the record on one side or the other proved defective, and then the good records were used. As there were four instruments, and generally four or five runs at each speed for each set-up, and three set-ups at adjacent locations, the value of the stress reported for a given driver at a given speed and for a given test section is generally the average of about a hundred records, and thus may be considered to be representative. It should be repeated that the stresses reported are the fiber stresses in the base of the rail at the mid-point of the gauge lines as reduced from the measured strains. As the instruments were placed between ties, the measurement of stress for positive moment occurred with the driver between ties. The measurement of maximum stress for a negative moment depended on the wheel spacing, occurring when the adjacent drivers of the Mikado locomotive were over ties and when the drivers of the Atlantic locomotive were between ties.

In Figs. 69 to 91 the data obtained in the tests on the Illinois Central Railroad are presented in graphical form for the three types of locomotive used. For each speed, the stress under each wheel has been plotted, and also the stress at the point of maximum negative moment between wheels. The scale of the stress is to be taken as beginning under the wheel for the positive moment stress and at the point between wheels indicated for the negative moment stress. Straight lines have been drawn to give the general trend of the stresses. The type of locomotive and descriptive items concerning the track and its condition are noted on the diagrams. The stresses indicated by the straight lines on these diagrams were considered to be representative of the average stresses for the given conditions. The averages of all the values given by the straight lines have been taken for two speeds, and have been plotted for both positive and negative moments on Figs. 92 to 97. As has already been noted, the type of instrument used in the 1915 tests is less accurate than the newer instrument, and gives smaller values than the true ones. For this reason, the 1916 results will be used for comparisons wherever possible.

46.—Stresses in Rail: Tests on D., L. & W. R. R.—Figs. 98 to 101 give speed-stress diagrams obtained from the data of the tests on the Delaware, Lackawanna and Western Railroad near Dover, N. J., for the four locomotives used. The values given by the straight lines on these diagrams have been taken for two speeds, and have been plotted for both positive and negative moments in Figs. 102 to 105.

47.—Modulus of Elasticity of Rail-support.—The term "modulus of elasticity of rail-support" has already been defined as the pressure per unit of length of each rail required to depress the track one unit. It measures the vertical stiffness of the support of the rail. The

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.

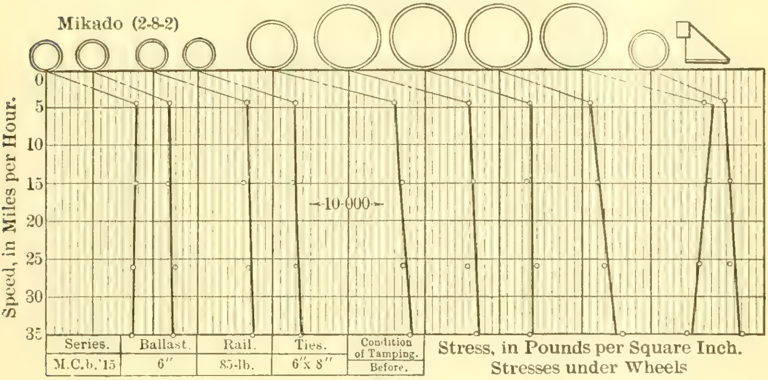


FIG. 69–a.

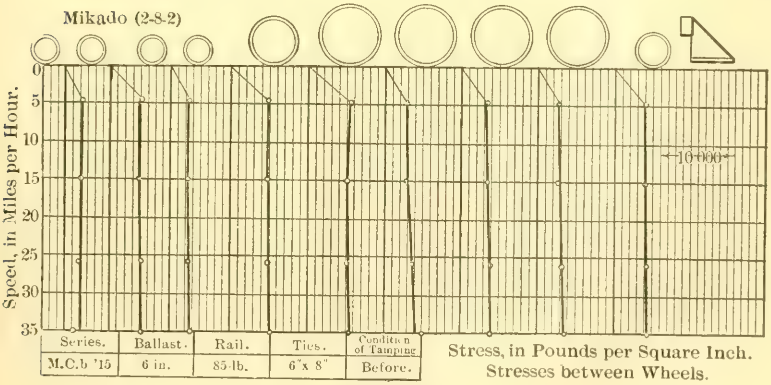


FIG. 69–b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.

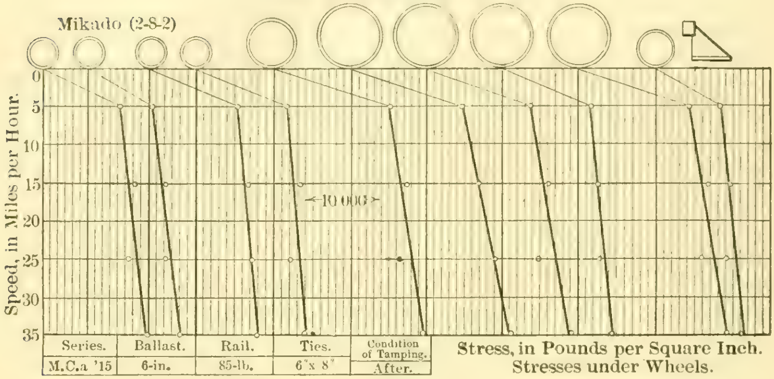


FIG. 70–a.

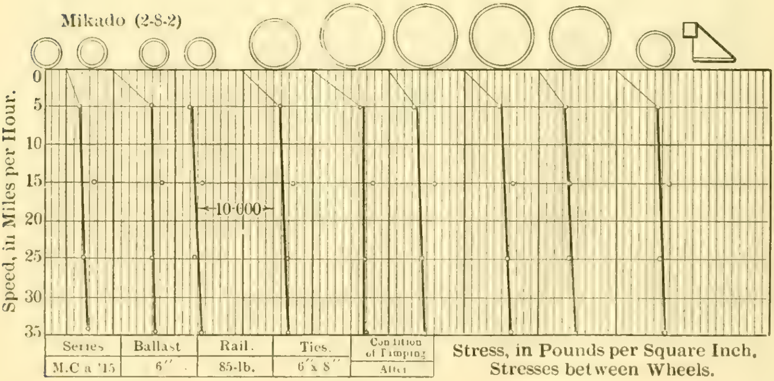


FIG. 70–b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.

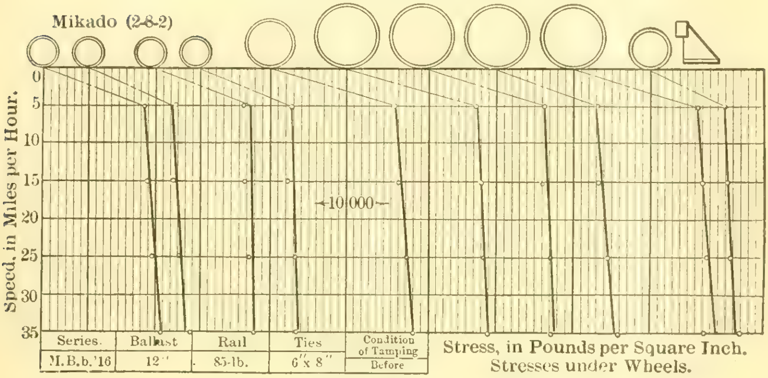


FIG. 71–a.

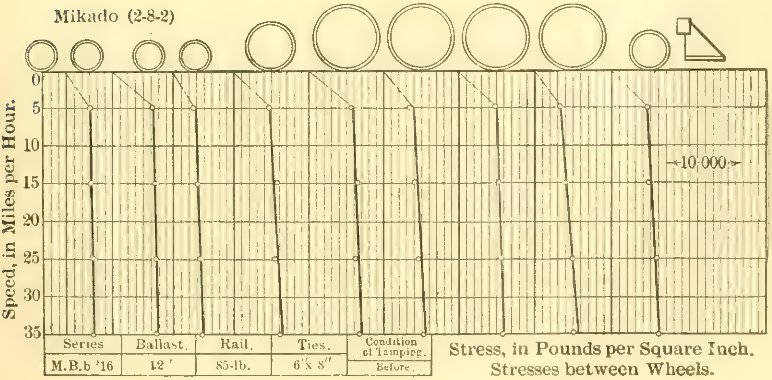


FIG. 71–b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.

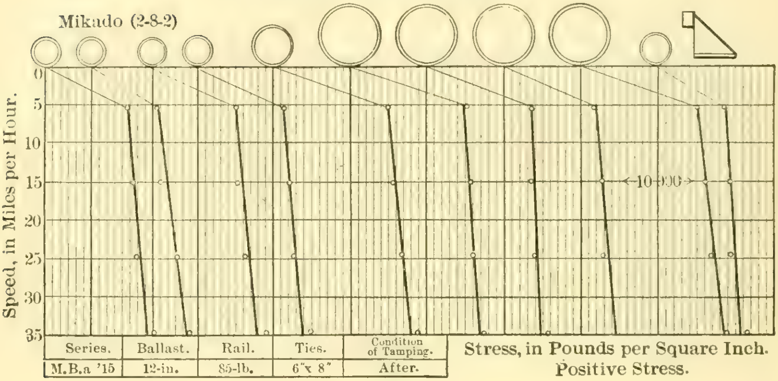


FIG. 72–a.

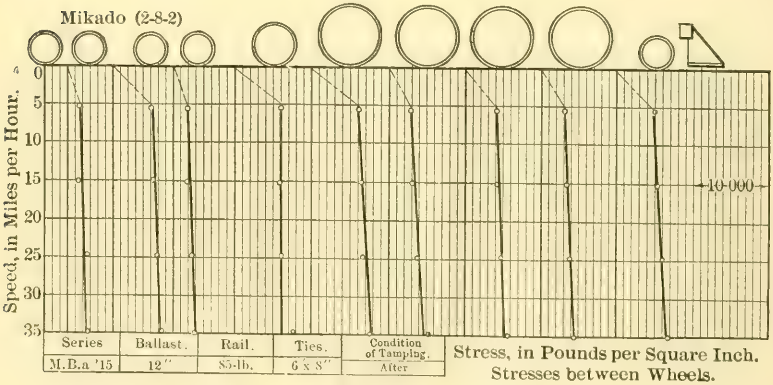


FIG. 72–b.

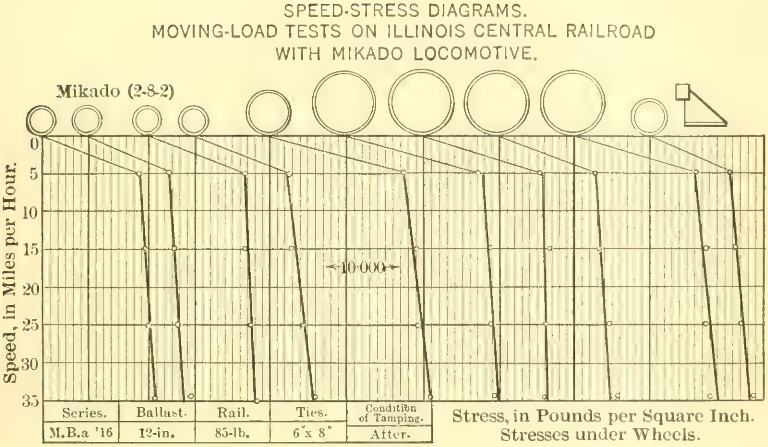

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.

FIG. 73–a.

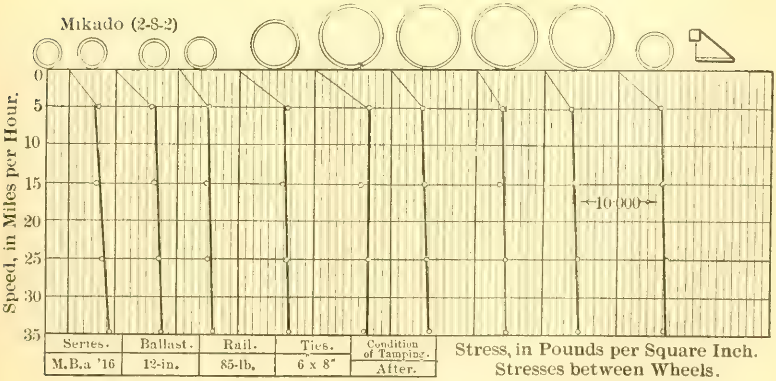
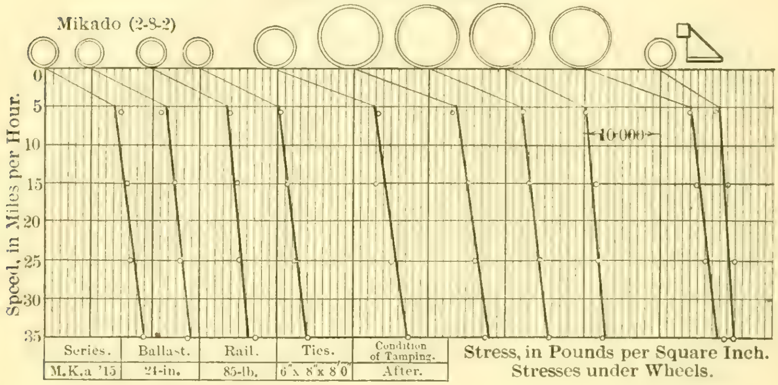


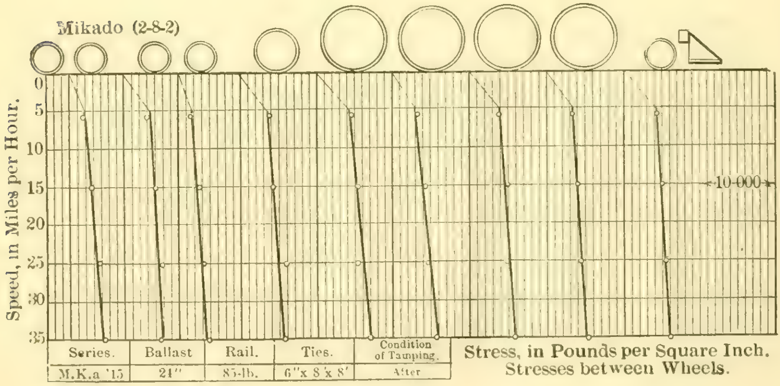
FIG. 73–b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.



Series.	Ballast.	Rail.	Ties.	Condition of Tamping.
M.K.a '15	24-in.	85-lb.	6″ x 8″ x 8′ 0″	After.

FIG. 74–a.



Series.	Ballast	Rail.	Ties.	Condition of Tamping.
M.K.a '15	24″	85-lb.	6″ x 8′ x 8′	After

FIG. 74–b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.

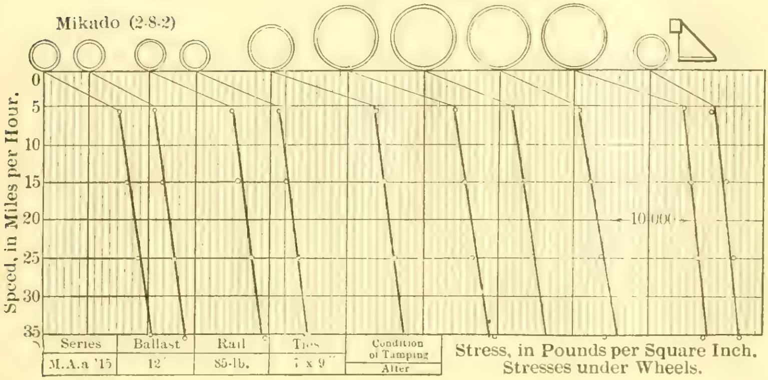


FIG. 75–a.

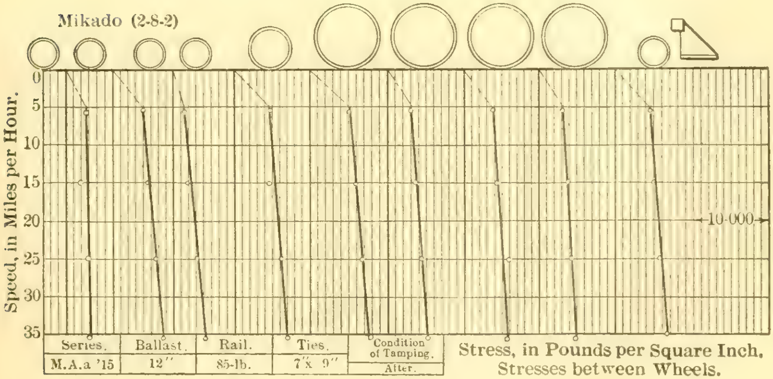


FIG. 75 b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.

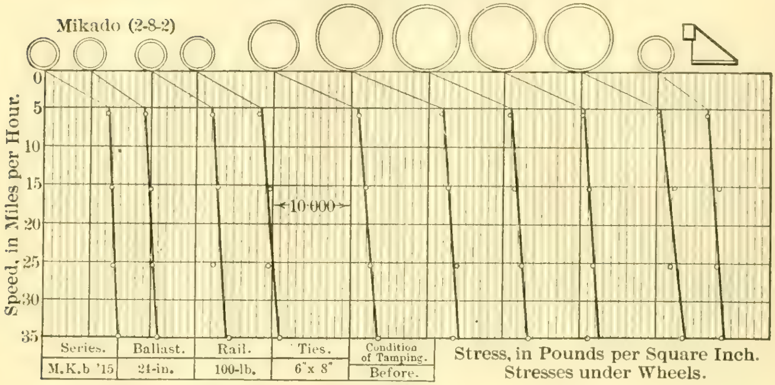


FIG. 76–a.

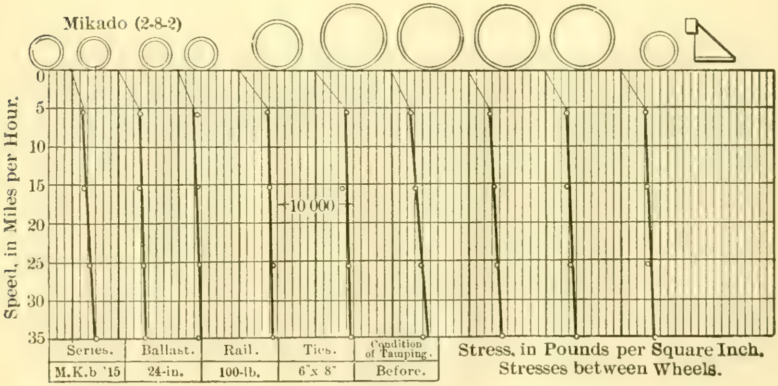


FIG. 76–b.

SPEED-STRESS DIAGRAMS.

MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE

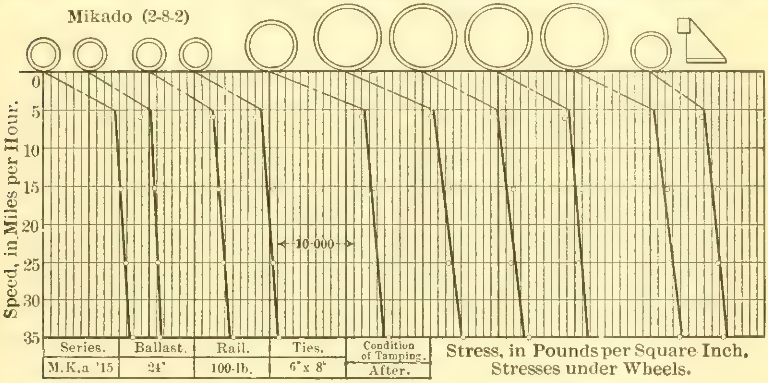


Fig. 77–a.

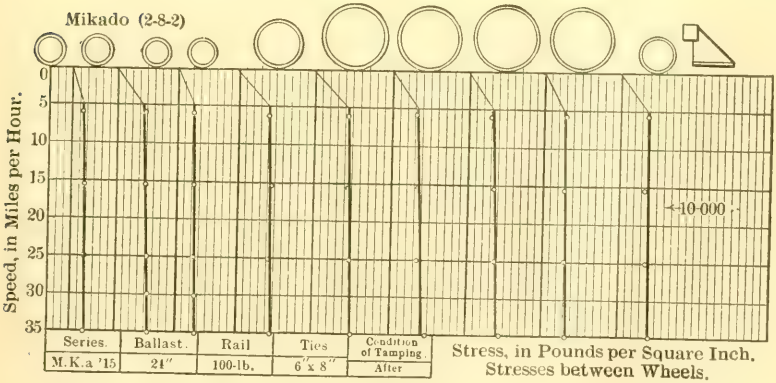


Fig. 77–b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.

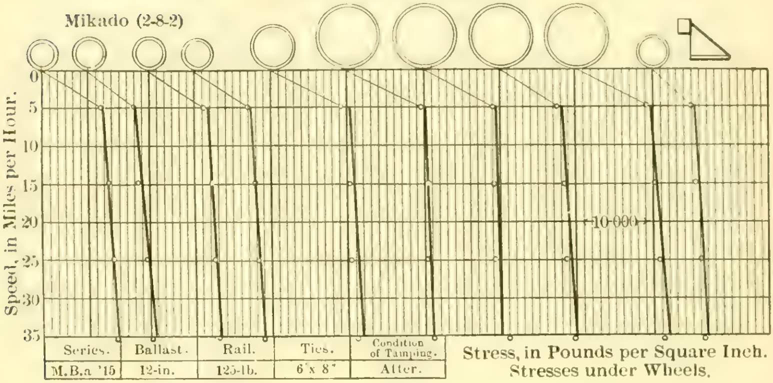


FIG. 78 a.

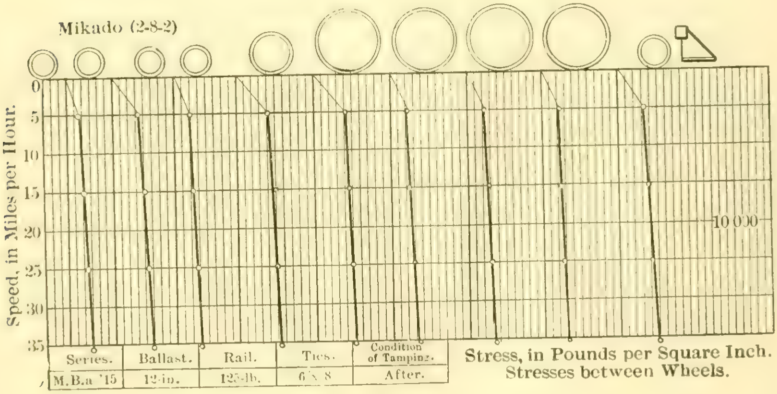


FIG. 78–b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.

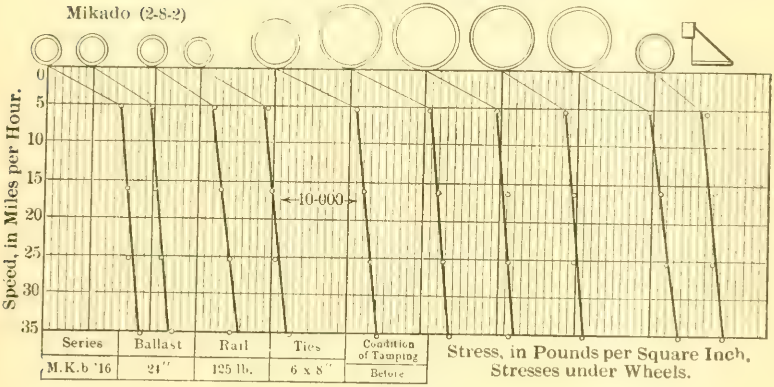


FIG. 79–a.

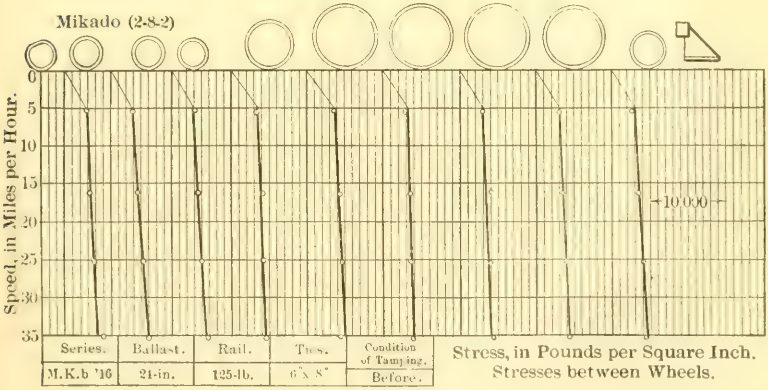


FIG. 79–b.

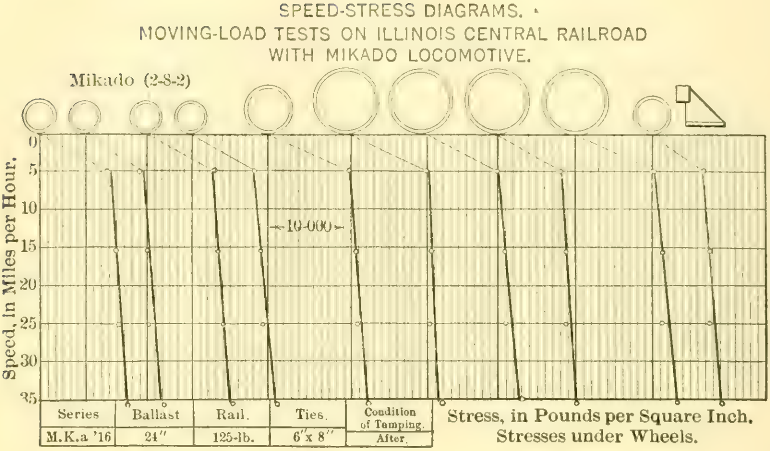


FIG. 80–a.

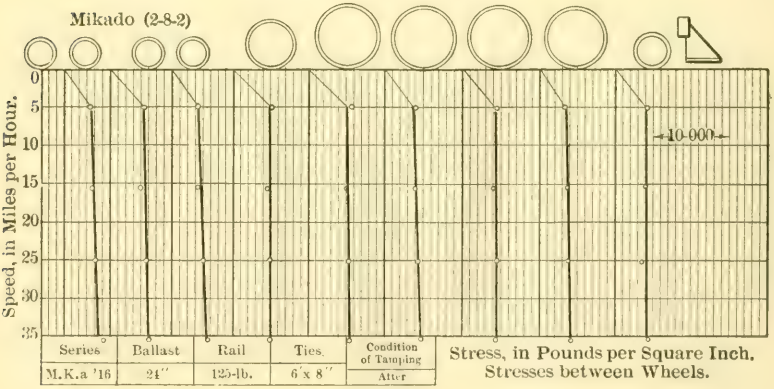


FIG. 80–b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.

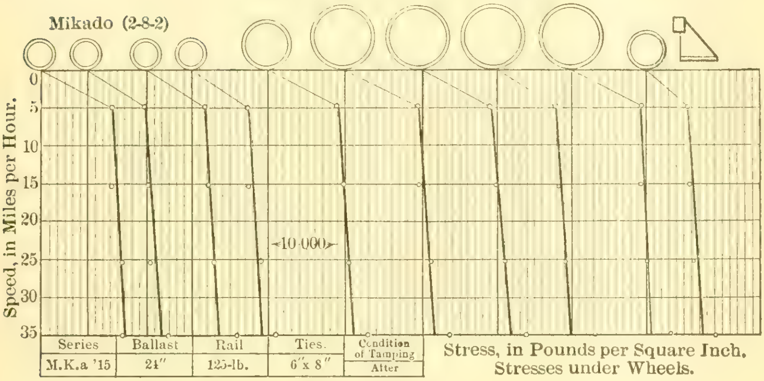


FIG. 81–a.

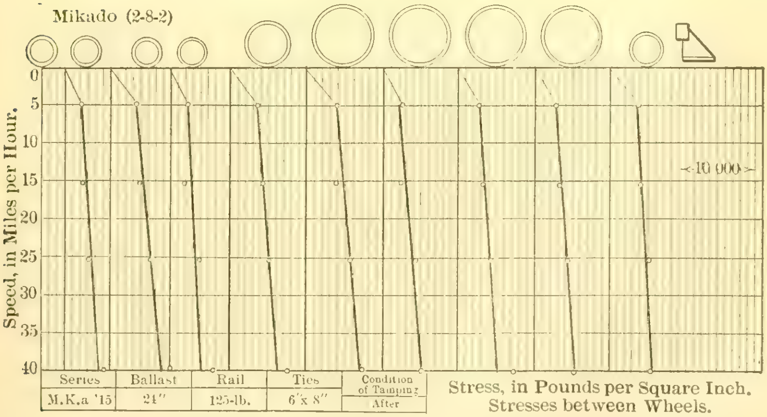


FIG. 81–b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH ATLANTIC LOCOMOTIVE.

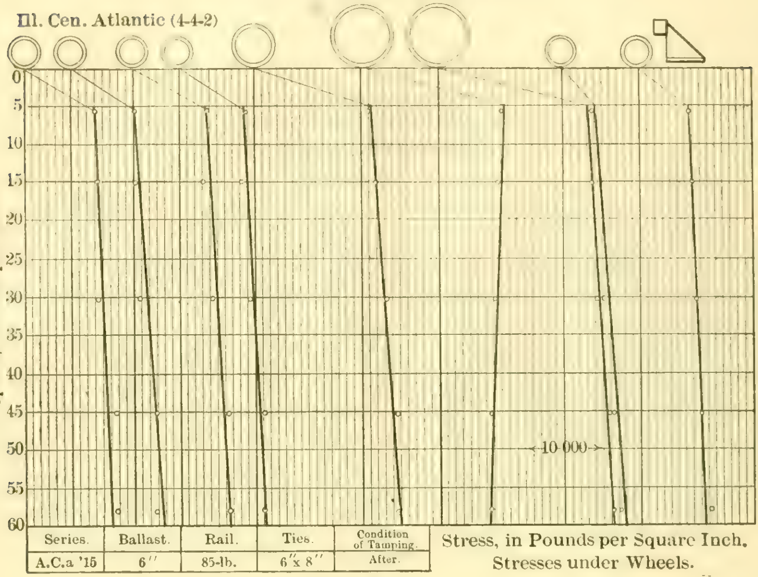


FIG. 82–a.

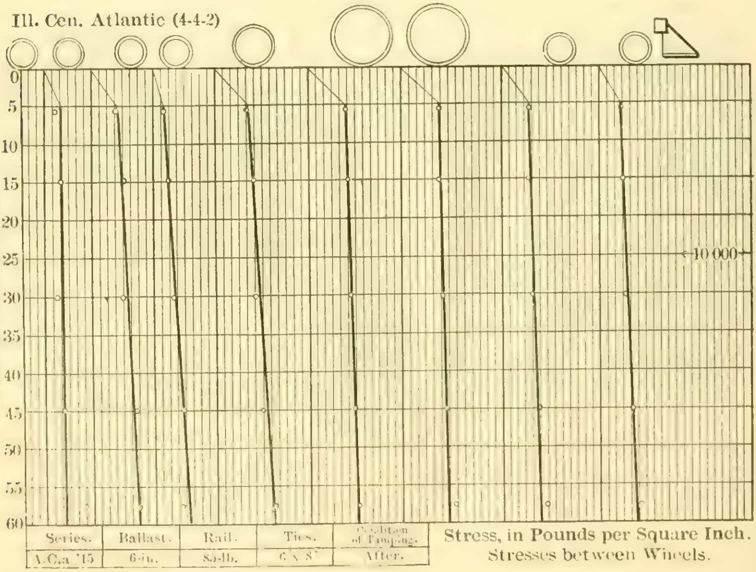
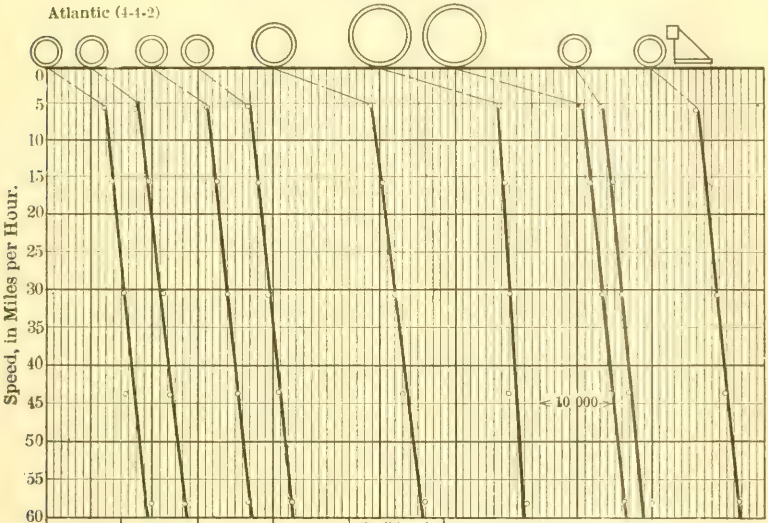


FIG. 82–b.

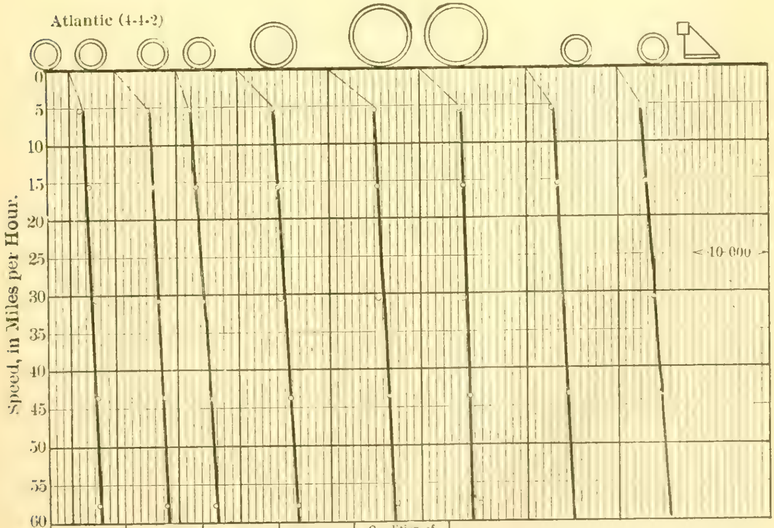
SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH ATLANTIC LOCOMOTIVE.



Series.	Ballast	Rail.	Ties.	Condition of Tamping.
A.B.a '16	12″	85-lb	6″x 8″	After.

Stress in Pounds per Square Inch.
Stresses under Wheels.

FIG. 83–a.



Series.	Ballast	Rail.	Ties.	Condition of Tamping.
A.B.a '16	12″	85-lb	6″x 8″	After

Stress in Pounds per Square Inch.
Stresses between Wheels.

FIG. 83–b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH ATLANTIC LOCOMOTIVE.

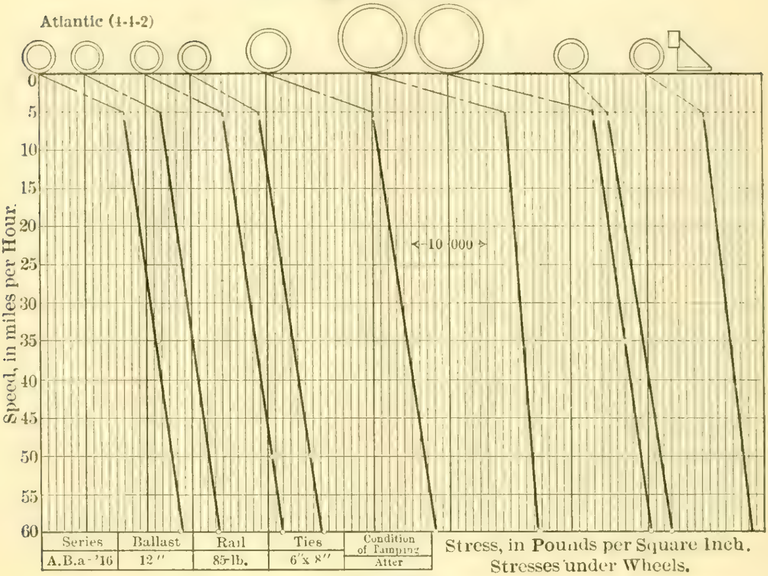


FIG. 84–a.

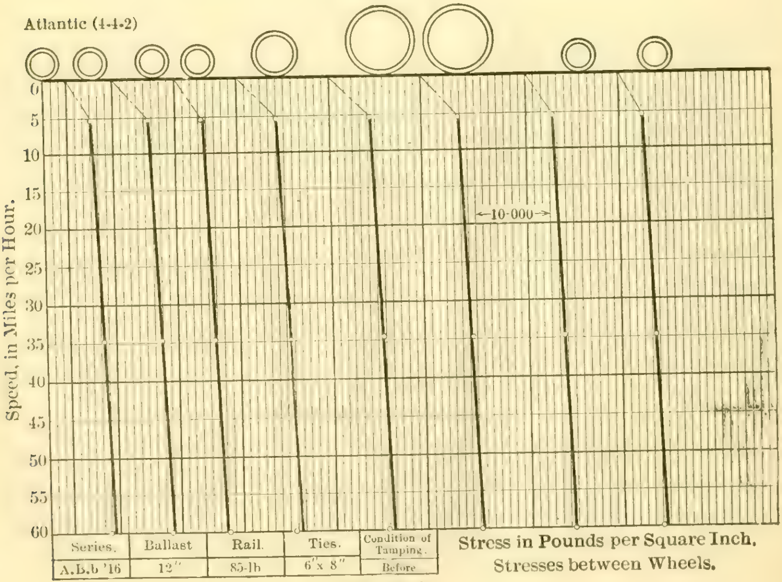


FIG. 84–b.

SPEED-STRESS DIAGRAMS
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH ATLANTIC LOCOMOTIVE.

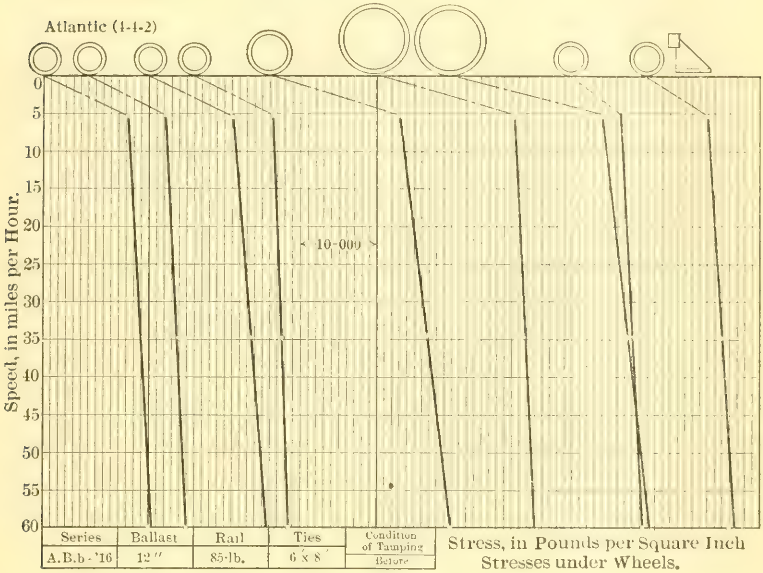


FIG. 85–a.

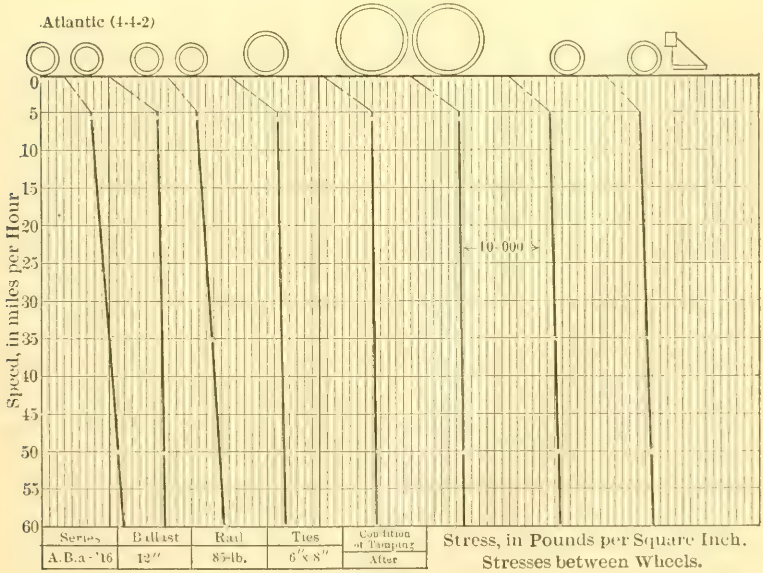


FIG. 85–b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH ATLANTIC LOCOMOTIVE.

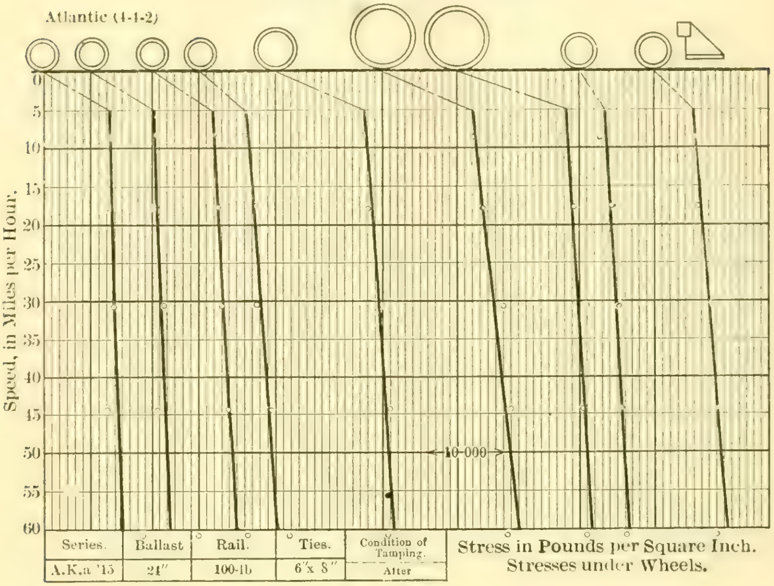


FIG. 86–a.

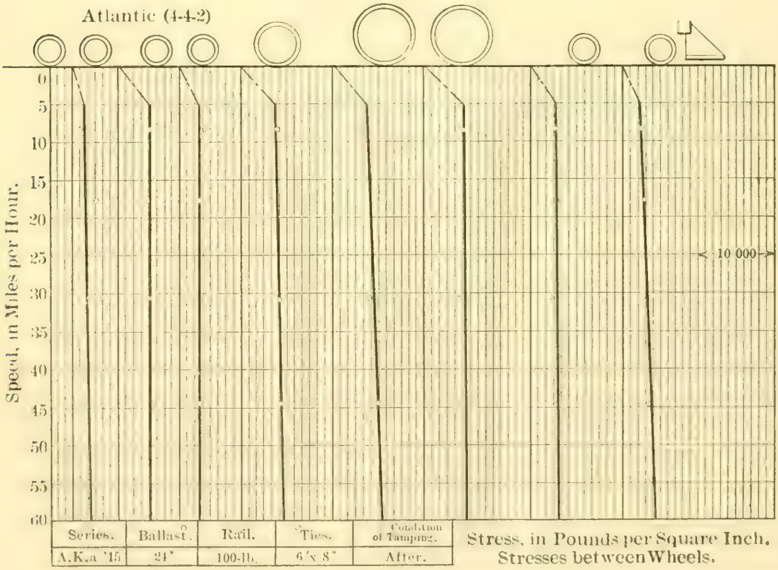
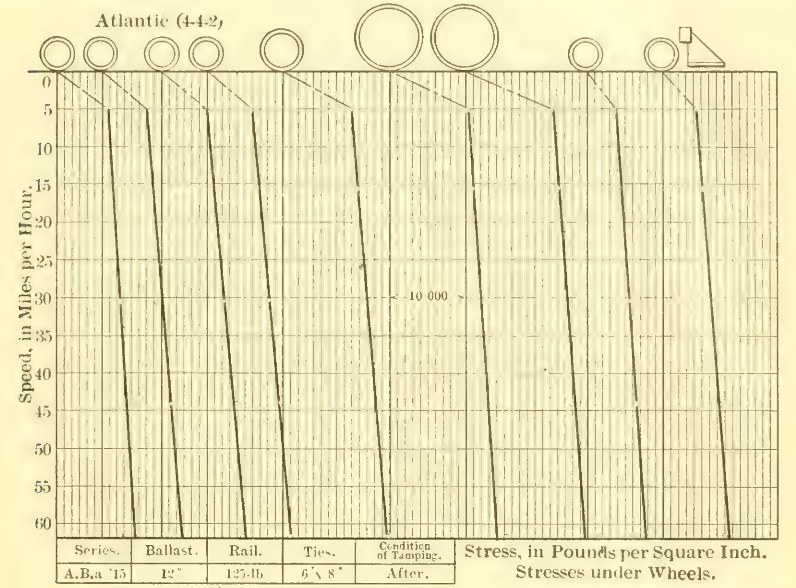


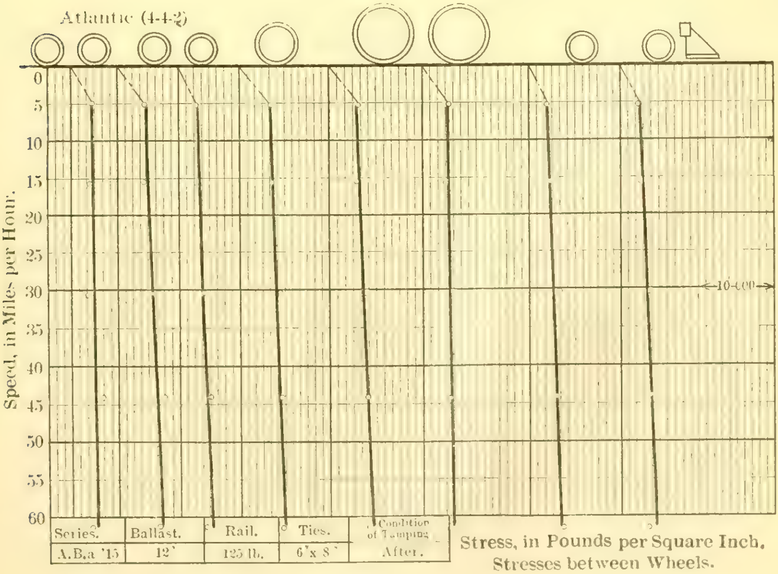
FIG. 86–b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH ATLANTIC LOCOMOTIVE.



Series.	Ballast.	Rail.	Ties.	Condition of Tamping.
A.B.a '15	12"	125-lb	6"x 8"	After.

FIG. 87–a.



Series.	Ballast.	Rail.	Ties.	Condition of Tamping.
A.B.a '15	12"	125 lb.	6"x 8"	After.

FIG. 87–b.

SPEED-STRESS DIAGRAMS.

MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH ATLANTIC LOCOMOTIVE.

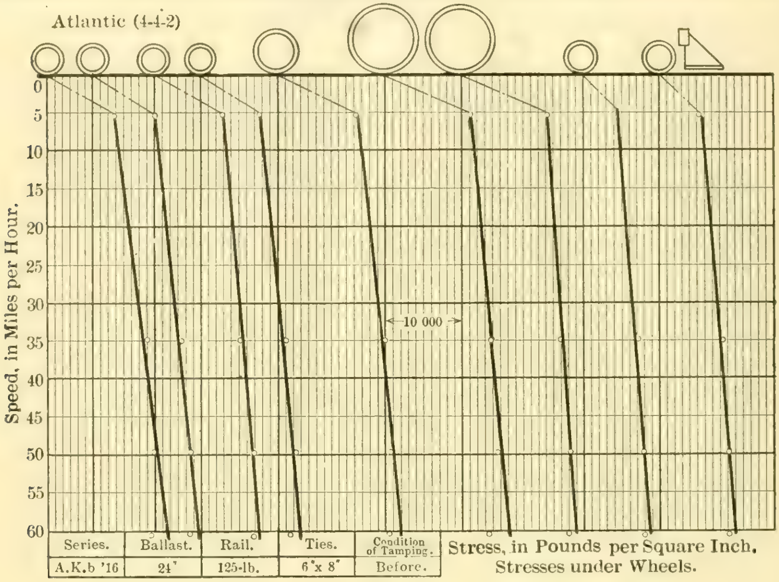


FIG. 88–a.

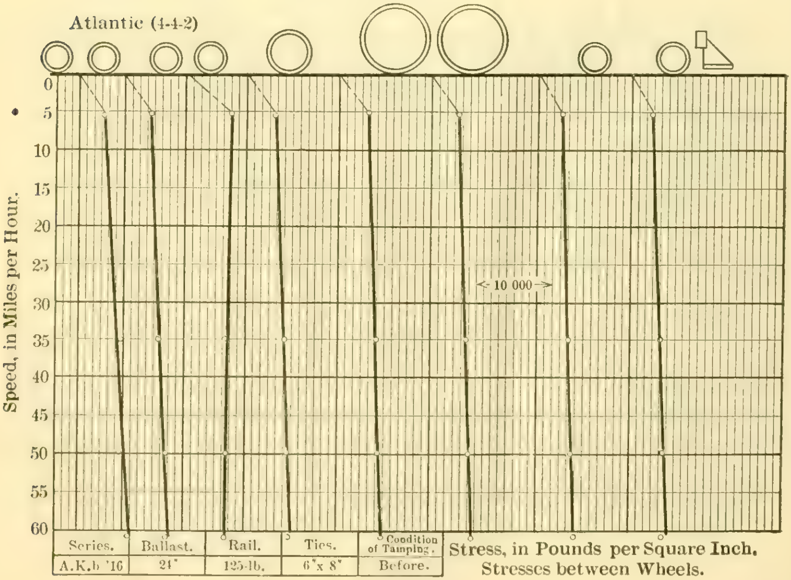


FIG. 88–b.

SPEED-STRESS DIAGRAMS.

MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH ATLANTIC LOCOMOTIVE.

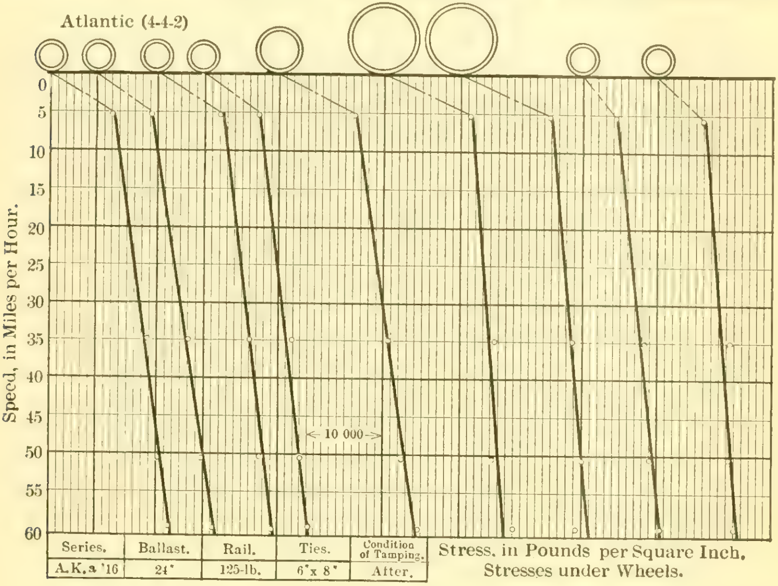


FIG. 89–a.

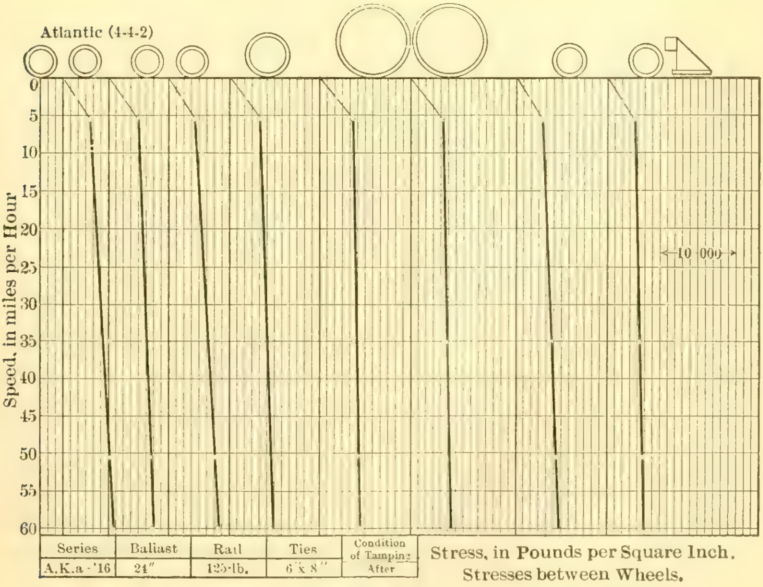
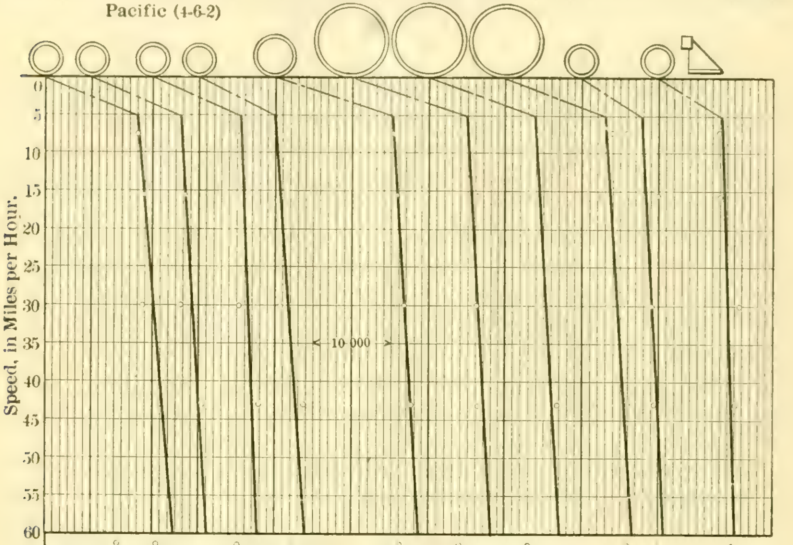


FIG. 89–b.

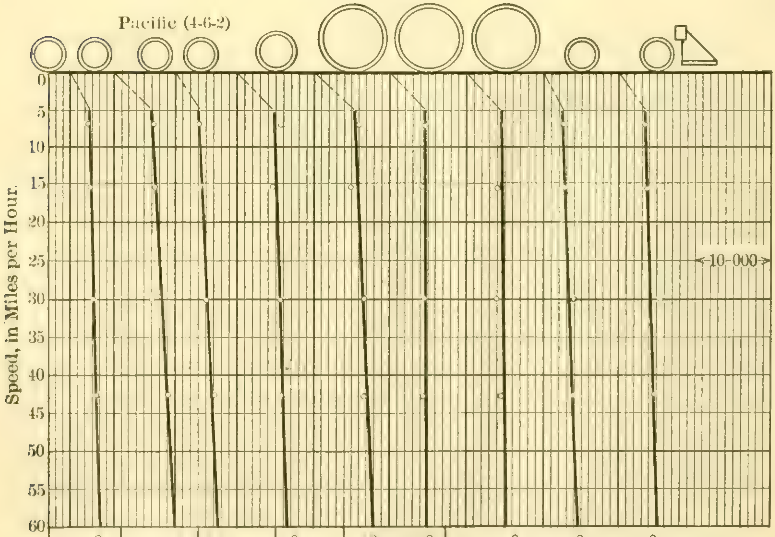
SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH PACIFIC LOCOMOTIVE.



Series.	Ballast.	Rail.	Ties.	Condition of Tamping.
P.B.a '15	12"	85-lb.	6"x 8"	After.

Stress, in Pounds per Square Inch.
Stresses under Wheels.

FIG. 90 a.



Series.	Ballast.	Rail.	Ties.	Condition of Tamping.
P.B.a '15	12"	85-lb.	6"x 8"	After.

Stress, in Pounds per Square Inch.
Stresses between Wheels.

FIG. 90–b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH PACIFIC LOCOMOTIVE.

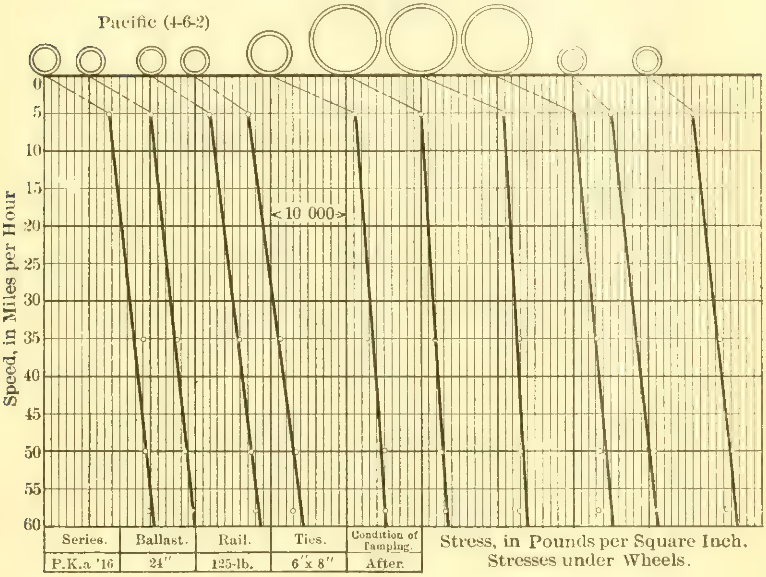


FIG. 91–a.

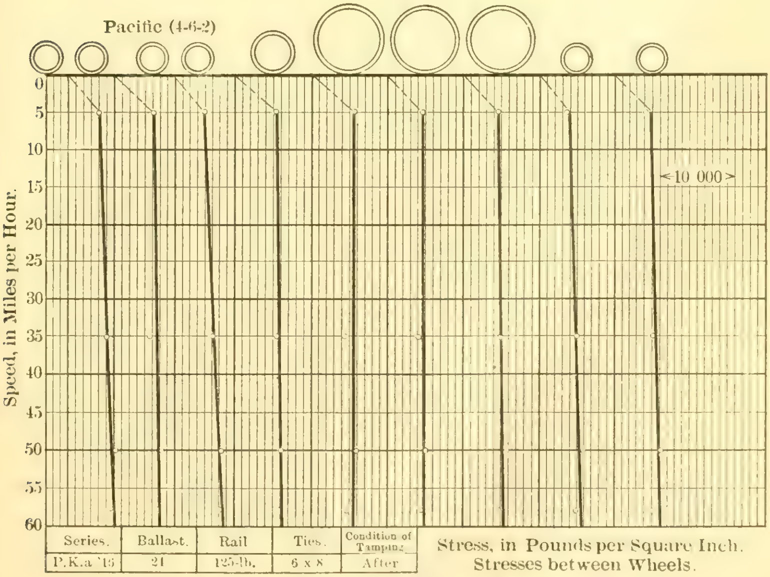


FIG. 91–b.

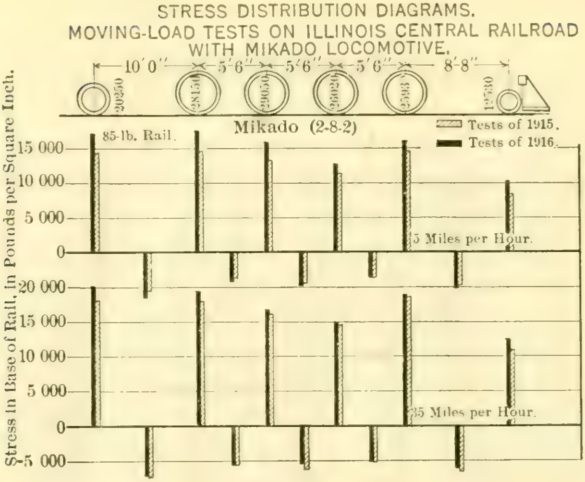


FIG. 92.

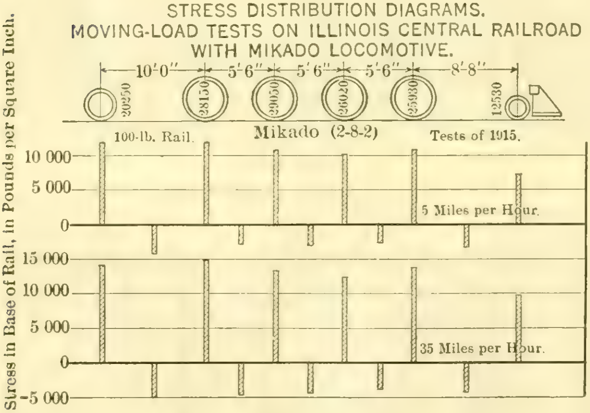


FIG. 93.

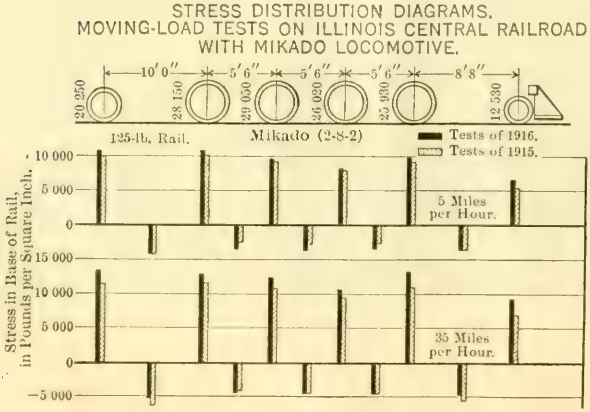


FIG. 94.

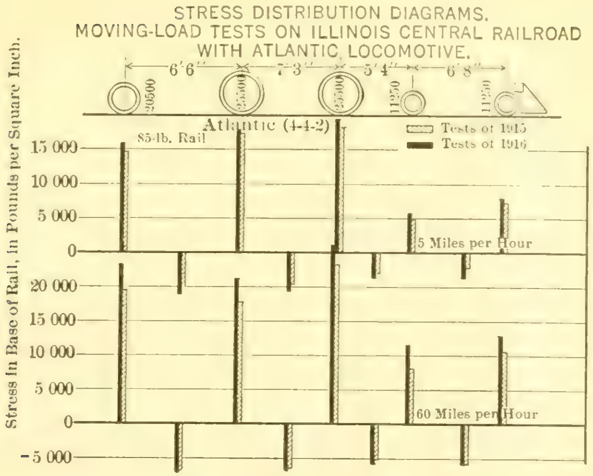


FIG. 95.

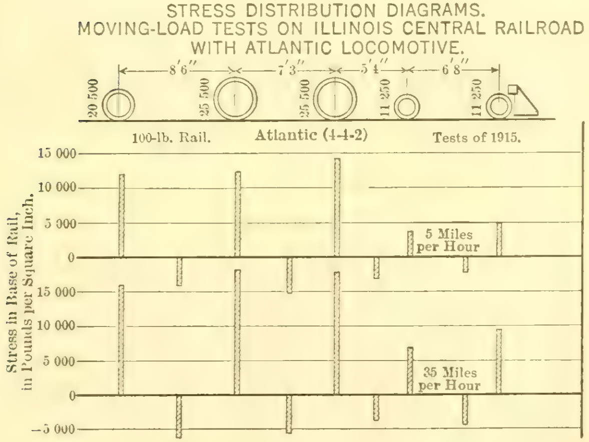


FIG. 96.

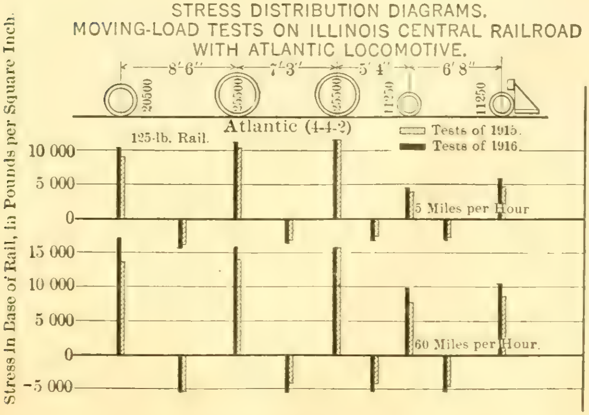


FIG. 97.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON D.L. & W.R.R. WITH MIKADO LOCOMOTIVE.

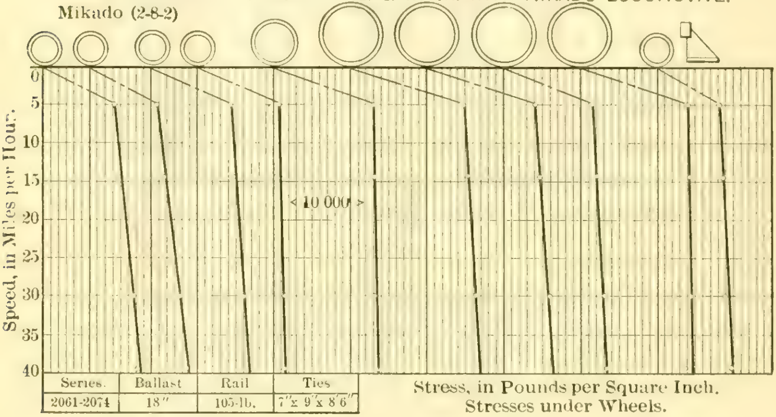


FIG. 98--a.

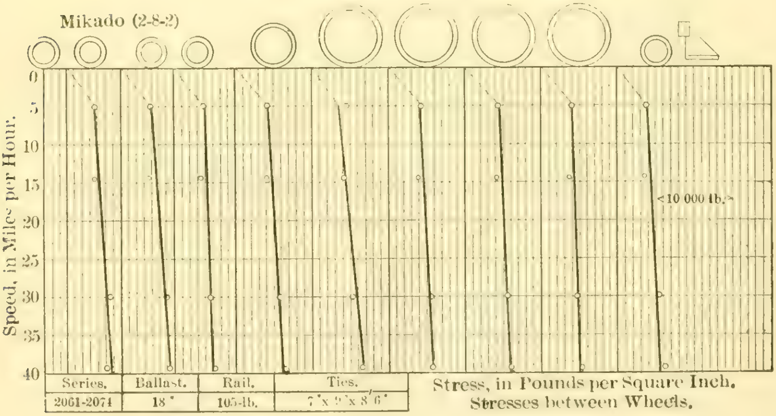


FIG. 98–b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON D.L. & W.R.R. WITH PACIFIC FREIGHT LOCOMOTIVE.

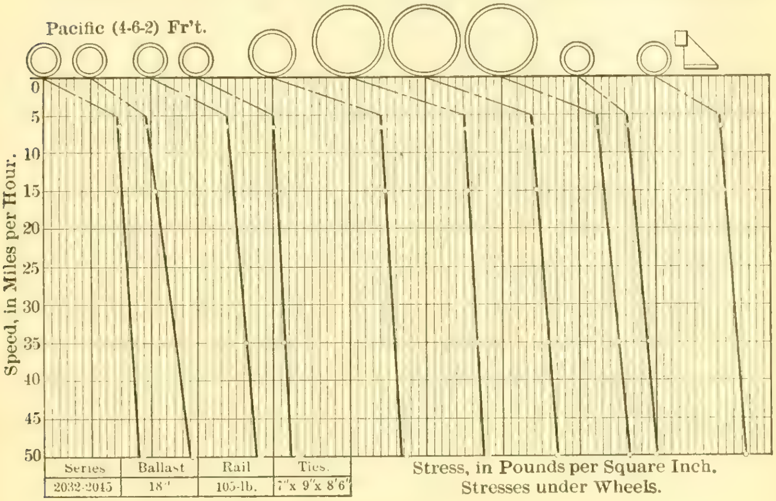


FIG. 99—a.

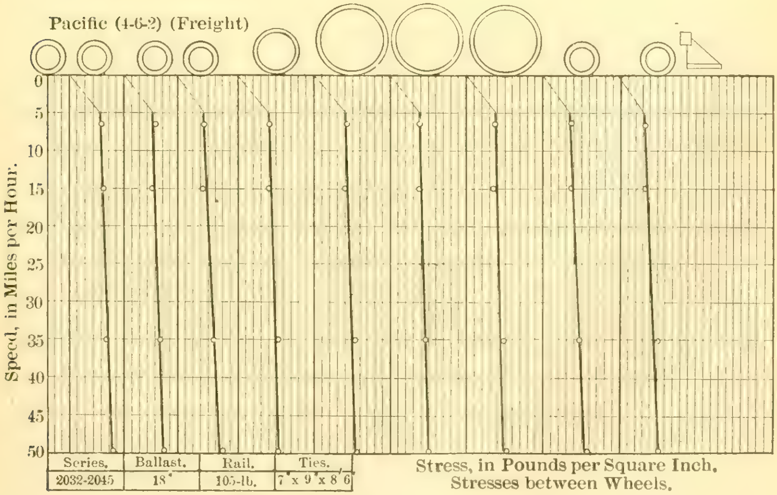


FIG. 99—b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON D.L. & W.R.R. WITH PACIFIC PASSENGER LOCOMOTIVE.

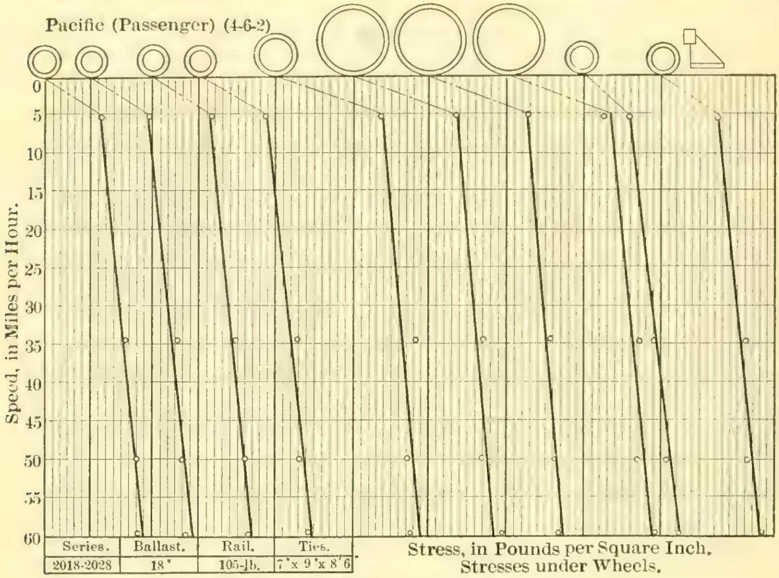


Fig. 100–a.

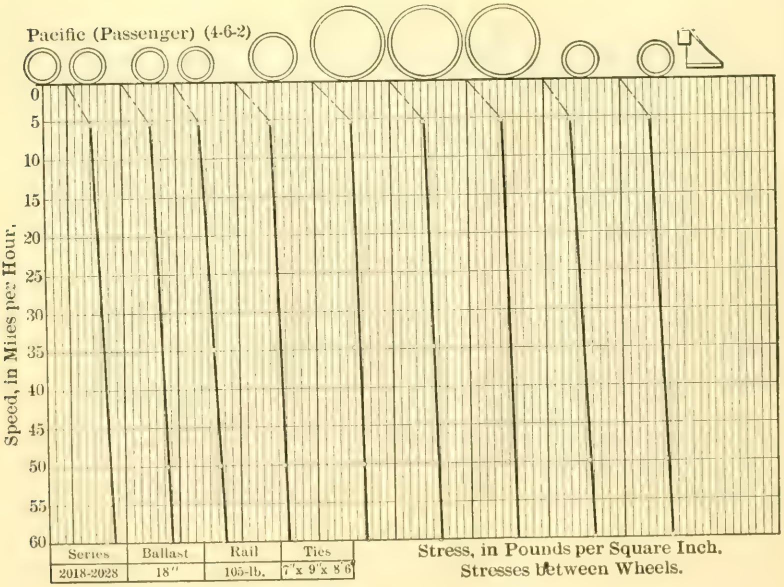


Fig. 100–b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON D.L. & W.R.R. WITH TEN-WHEEL LOCOMOTIVE.

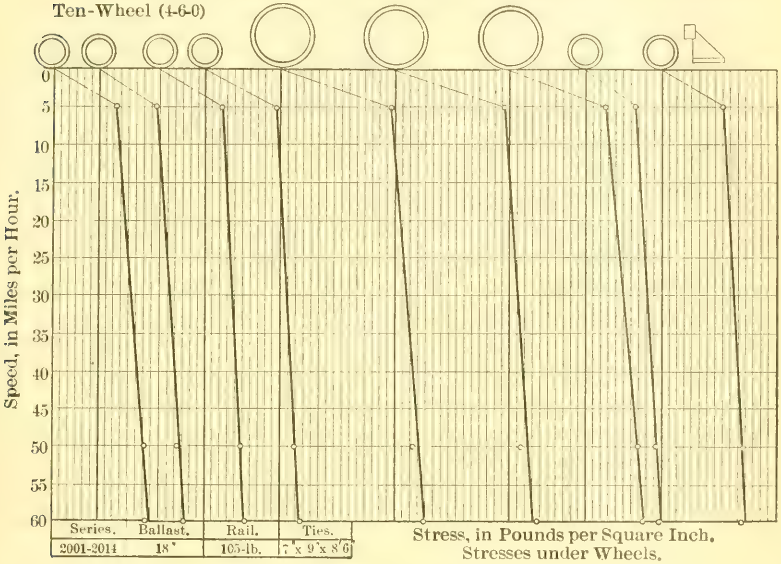


FIG. 101–a.

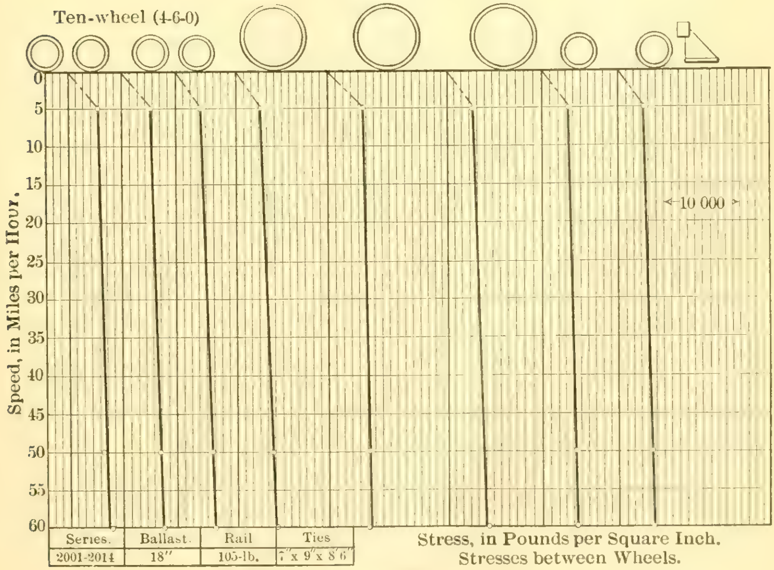


FIG. 101–b.

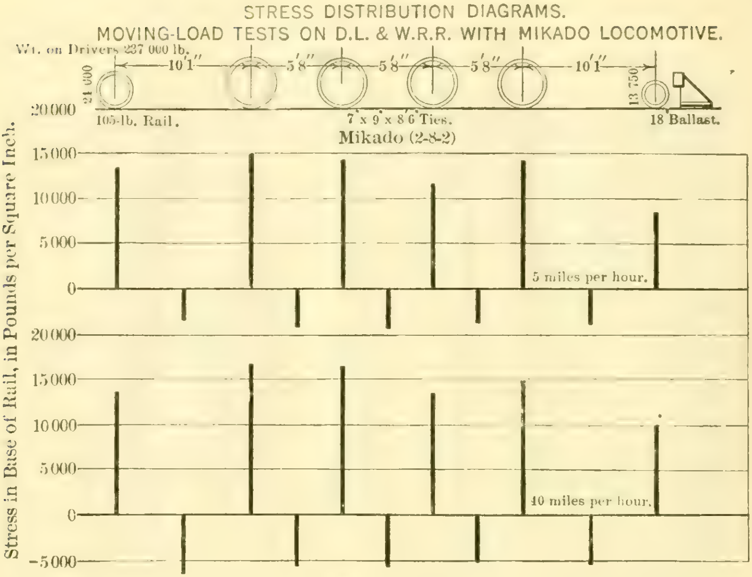


FIG. 102.

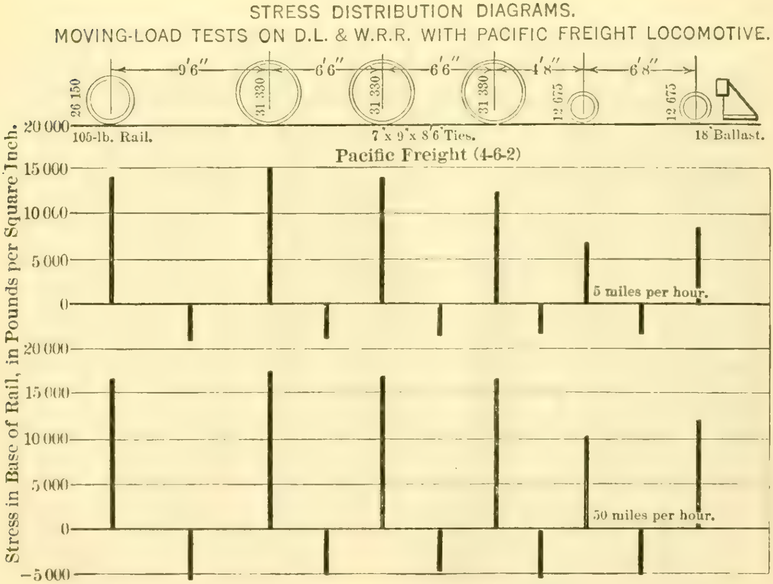


FIG. 103.

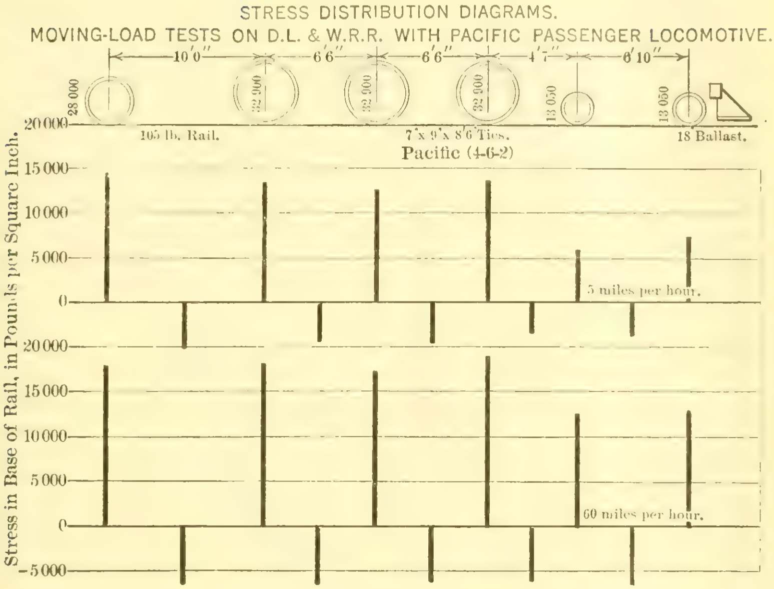

STRESS DISTRIBUTION DIAGRAMS.
MOVING-LOAD TESTS ON D.L. & W.R.R. WITH PACIFIC PASSENGER LOCOMOTIVE.

FIG. 104.

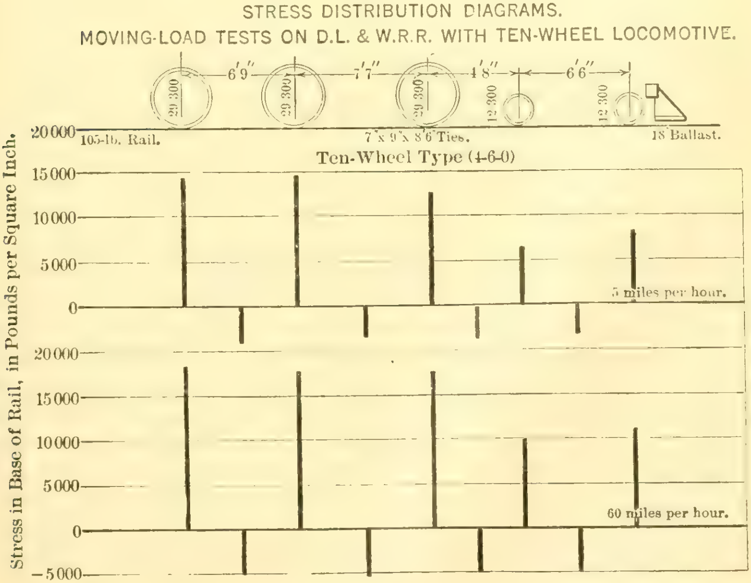

STRESS DISTRIBUTION DIAGRAMS.
MOVING-LOAD TESTS ON D.L. & W.R.R. WITH TEN-WHEEL LOCOMOTIVE.

FIG. 105.

magnitude of the modulus of elasticity of rail-support is dependent on a number of elements, such as the compressibility of the tie and its flexural stiffness, the breadth and length of the tie, the tie spacing, the character of the bearing of the tie on the ballast, the thickness, solidification, and stiffness of the ballast, the nature of the roadway, and the way in which the pressures are distributed over it. As the stresses developed in the rail and the division of load among tie reactions are affected directly by the magnitude of the modulus of elasticity of rail-support, this modulus may serve as one criterion of the quality of track. It will be of interest, therefore, to learn what range of values of the modulus of elasticity of rail-support may be expected for various kinds and conditions of track.

The definition of the term implies that the modulus of elasticity of rail-support is a constant for any given condition of track, that the track has the usual property of an elastic body. In the discussion of the data on track depression, it was shown that the depression of track may not be proportional to the load applied; under such conditions, the modulus of elasticity of rail-support would not be a constant. The tests indicate conditions of track which may be classified in three groups: The plotted depressions may give a straight line passing through the origin, as at *a,* Fig. 106, denoting a constant modulus of elasticity—a condition which may be expected in well-tamped track, and where the tie has a full bearing immediately below the rail and for some distance each way along its length, even when only a small load is applied. The plotted depression may form a straight line which passes to the right of the origin, as at *b*, denoting that some condition exists such as the presence of some play between tie and ballast immediately below the rail necessitating the bending of the tie before a full and fair bearing is obtained along its length; in this case the depression may be found by the use of a constant modulus of elasticity of rail-support plus a constant. At *c* the condition is similar, except that the points do not give a straight line relation; in this case the relation of depression to load may be approximated by a constant modulus of elasticity of rail-support drawn to pass the points somewhat as shown in the figure. For track in poor condition, the relation of depression to load may be expected to vary from the straight-line relation even more than shown in the figure. As conditions of track vary greatly, the relation between track depression and load may be expected to cover a considerable range of values and conditions. It is evident that the constant modulus of elasticity of rail-support applies very well to the conditions of best track, and that, for poor and indifferent track, the actual relation between depression and load departs considerably from a straight-line relation.

Values of the modulus of elasticity of rail-support have been calculated from the data of the track depressions by adding the depressions at the several ties for the length of the depressed track or for the length for which the loads used are considered to affect the track depressions. The total load on the wheels within the length used was then divided by the number of ties in this length, and by the tie spacing, in inches. The values of the modulus of elasticity of rail-support are thus given in pounds per inch of length of rail per inch of depression. The symbol, u, is used to represent it. A continuous load of u pounds per inch of rail on each rail would depress the track 1 in. For the locomotive loading, in computing the modulus of elasticity of rail-support the total track depression was used; the static tests with locomotive were all made on track in well-tamped condition. For the one-axle and two-axle load tests, the lines of the load-depression diagrams were studied, and here some allowance was made for the play at light load for track conditions which gave indications of such play, net track depressions being used for the calculations. In some cases a general compromise straight line was used. The values reported are given tentatively, and may need empirical modifications later in order to fit into other experimental data.

TYPICAL LOAD-DEPRESSION DIAGRAMS.

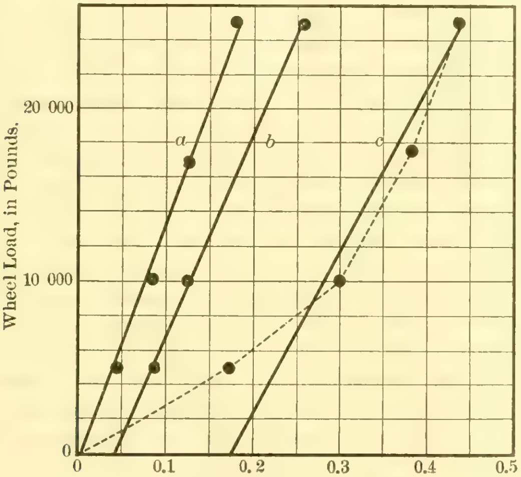


FIG. 106.

Table 4 gives the values of the modulus of elasticity of rail-support as calculated from the track depressions. The conditions of track are not stated very definitely, but, even in track marked "before tamping", the track was in good surface, and only in a few instances was it in need of tamping. The values derived from the tests for the different methods of loading on the same track agree very well. There seems to be some tendency toward a higher value of the modulus in the track having the heaviest rail. It is apparent that the character and condition of the track greatly influence the magnitude of the modulus of elasticity of rail-support. The value for the modulus on the track of the Illinois Central Railroad with 24-in. ballast may be taken as about 1 600 lb. per in. per in. This test stretch is on the north-bound track. For the track on 6-in. and 12-in. ballast, the values are approximately 1 000, except for the track on 7 by 9-in. ties, where the values are higher, say, about 1 200. These last-named stretches of test track are on the south-bound track. Although the embankment for the two tracks was built at different times, it is not known that the two parts of the embankment have any special differences in condition. In all these test stretches, there is a tie spacing of 22 in. where the tests were made. For the track used for freight service, which was ballasted with 6 in. of cinders in not very compact condition, the value of the modulus of elasticity of rail-support is about 750. For the track of the Champaign and Havana Branch of the Illinois Central Railroad, with about 6 in. of fine cinder ballast above a light embankment of loam, tie spacing varying from 22 to 26 in. (56-lb. rail), the modulus of elasticity of rail-support found was about 530. At the time, the track was not in good condition at the point where the test was made. Some of the ties were partly decayed.

For the track of the Delaware, Lackawanna and Western Railroad, information on the depression of track and the condition of the track is not complete, and only an estimated value of the modulus of elasticity of rail-support can be given. This track was evidently stiffer than that of the Illinois Central Railroad. The value, 2 200 lb. per in. per in., is probably representative of this track. The track had 18 in. of trap rock ballast below the tie, and the material of the roadway below was such that it was very solid. The spacing of the 7 by 9-in. by 8 ft. 6-in. ties averaged about 22 in.

48.—Bending Moment Coefficient and Stresses in Rail.—It will be convenient, in making calculations and comparisons, to use the term "bending moment coefficient" as the coefficient by which the wheel load, *P*, may be multiplied to find the bending moment in the rail at a given point. Generally, the term will refer to the bending moment directly under a wheel load. In the case of a combination of wheels, the moment under a wheel will be expressed in terms of the wheel load at the given point. The bending moment coefficient will also be used in connection with the maximum negative bending moment. In this case, the wheel load used in connection with the coefficient should be specified. The symbol, K, will represent the bending moment coefficient. The sections of the rails used in the tests are shown in Fig. 107. The properties of the sections are given in Table 5. In columns marked S, in Table 6, are recorded fiber stresses in base of rail derived from the tests on the Illinois Central Railroad, the values being averages of those plotted in Figs. 69 to 91. The stresses are given in thousands of pounds per square inch. Corresponding values of the bending moment coefficients are given in the columns to the right of the stresses (marked K). These were calculated from the stresses by the usual formula, $M = KP = \frac{S\,I}{c}$. For the negative moments between drivers, the average load on the adjacent drivers was used as P. For the negative moments between a driver and a truck or trailer, the load on the adjacent driver was used as P. It should be borne in mind that the tests were made on stretches of track having differing track conditions, and, in making comparisons, this should be taken into consideration.

TABLE 5.—PROPERTIES OF SECTIONS OF RAILS USED IN TESTS.

Rail section.	Area, in square inches.	MOMENT OF INERTIA.		SECTION MODULUS.		
		For horizontal axis.	For vertical axis.	HORIZONTAL AXIS.		VERTICAL AXIS.
				Base.	Head.	Base.
85-lb. Am. Soc. C. E. (worn)	7.85	27.0-in.^{4}	7.3-in.^{4}	11.1-in.^{3}	10.1-in.^{3}	2.79-in.^{3}
100-lb. Am. Soc. C. E.	9.84	44.0 "	10.7 "	16.1 "	14.5 "	3.72 "
105-lb. D. L. & W.	10.23	47.6 "	10.0 "	17.2 "	14.7 "	3.72 "
125-lb. P. R. R.	12.30	68.7 "	13.4 "	22.9 "	19.6 "	4.87 "

Table 7 gives stresses and bending moment coefficients obtained in a similar manner from the tests on the track of the Delaware, Lackawanna and Western Railroad.

The bending moment coefficients found in the tests with the several types of locomotive, given in the foregoing tables, are shown diagramatically in Figs. 108 to 117.

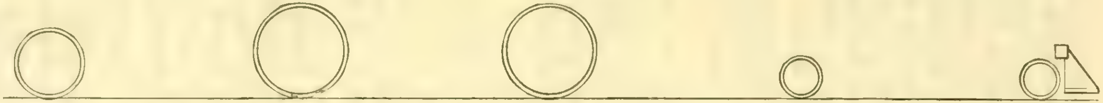
In Fig. 118 the stresses in the rail at speeds of 5 miles per hour and 35 or 60 miles per hour, taken from Table 6, are plotted for the three sections of rail.

Discussion of the results given in these tables and diagrams will be found in the following pages.

49.—Effect of Speed.—The position of the plotted points in Figs. 69 to 91 indicates that a rectilinear relation between stress in rail and speed of locomotive fits the data more generally and more satis-

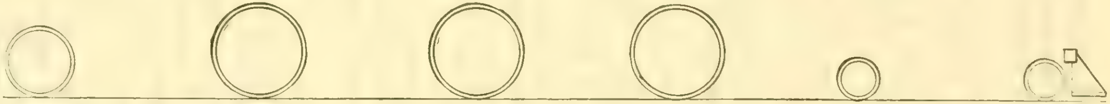
TABLE 6.—(*Continued.*)

ATLANTIC (4–4–2)



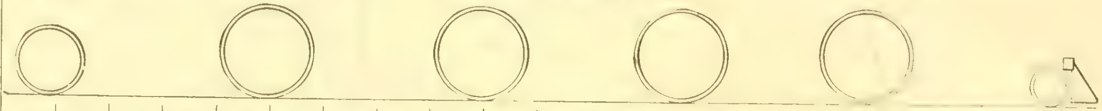
Weight of rail, in pounds per yard.	Year.	Speed, in miles per hour.	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*
85	1915	5	14.6	7.9	— 5.0	— 2.2	17.4	7.5	— 4.7	— 2.1	18.4	7.9	— 3.0	— 1.3	4.8	4.7	— 2.4	— 2.4	7.1	7.0
		60	19.4	10.6	— 7.4	— 3.2	17.7	7.7	— 6.5	— 2.8	23.2	10.1	— 5.2	— 2.3	8.0	7.9	— 5.8	— 5.7	10.4	10.3
85	1916	5	15.9	8.6	— 6.1	— 2.7	17.9	7.8	— 5.5	— 2.4	19.6	8.5	— 3.8	— 1.7	5.7	5.6	— 3.6	— 3.6	7.9	7.8
		60	23.3	12.6	— 7.4	— 3.3	21.2	9.3	— 7.0	— 3.2	26.1	11.4	— 5.7	— 2.5	11.5	11.2	— 5.8	— 5.8	12.8	12.9
100	1915	5	11.8	9.3	— 4.3	— 2.8	12.4	7.8	— 5.2	— 3.4	14.4	9.2	— 3.2	— 2.1	3.6	5.1	— 2.2	— 3.3	5.0	7.2
		60	15.7	12.3	— 6.5	— 4.1	18.2	11.5	— 5.5	— 3.5	17.7	11.2	— 3.7	— 2.3	6.6	9.5	— 4.4	— 6.3	9.5	13.7
125	1915	5	9.1	10.1	— 3.7	— 3.4	10.4	9.4	— 3.3	— 3.2	11.6	10.4	— 2.5	— 2.3	4.0	8.0	— 2.5	— 5.3	4.7	9.5
		60	13.6	14.7	— 5.4	— 4.8	13.9	12.5	— 4.0	— 3.6	15.6	14.0	— 4.2	— 3.8	7.6	15.5	— 4.6	— 9.4	8.5	17.3
125	1916	5	10.3	11.5	— 4.1	— 3.7	11.3	10.1	— 3.9	— 3.5	11.8	10.6	— 3.2	— 3.0	4.5	9.2	— 3.4	— 7.0	6.0	12.2
		60	17.2	19.2	— 5.6	— 5.1	15.8	14.2	— 5.4	— 4.9	15.9	14.2	— 5.2	— 4.7	9.8	19.7	— 5.0	—10.3	10.4	21.2

PACIFIC (4–6–2)



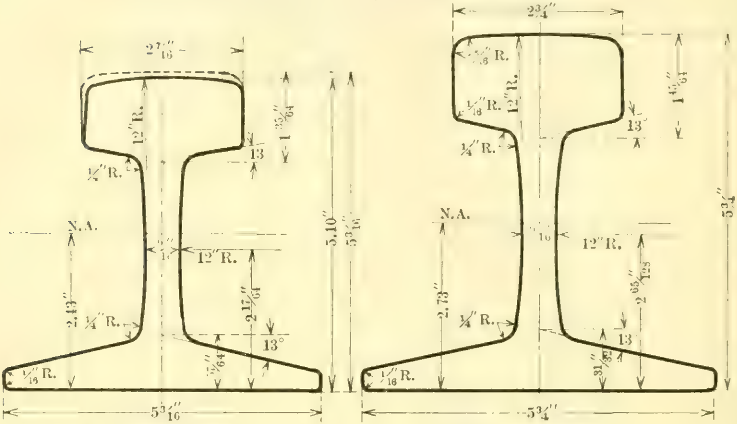
Weight of rail, in pounds per yard.	Year.	Speed, in miles per hour.	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*
85	1915	5	15.3	7.7	— 5.3	— 2.4	15.0	6.7	— 4.5	— 1.9	13.8	5.7	— 4.5	— 1.9	13.1	5.8	— 2.5	— 1.1	7.8	7.0	— 3.5	— 3.1	8.5	7.7
		60	18.9	9.5	— 7.9	— 3.5	18.2	8.1	— 4.8	— 2.1	17.2	7.1	— 5.2	— 2.2	16.7	7.4	— 4.5	— 2.0	10.7	9.7	— 5.0	— 4.5	10.1	9.1
125	1916	5	11.3	11.7	— 5.6	— 5.1	10.1	9.3	— 4.7	— 4.1	10.9	9.2	— 4.7	— 4.1	10.2	9.3	— 3.8	— 3.5	5.2	9.6	— 5.0	— 9.3	6.1	11.3
		60	15.3	15.9	— 5.5	— 5.0	13.5	12.3	— 5.0	— 4.4	14.0	11.8	— 5.3	— 4.7	14.9	13.6	— 5.7	— 5.2	11.7	21.6	— 6.3	—11.7	11.6	21.5

TABLE 6.—STRESSES IN RAILS, S, AND BENDING MOMENT COEFFICIENTS, K, FROM MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD.



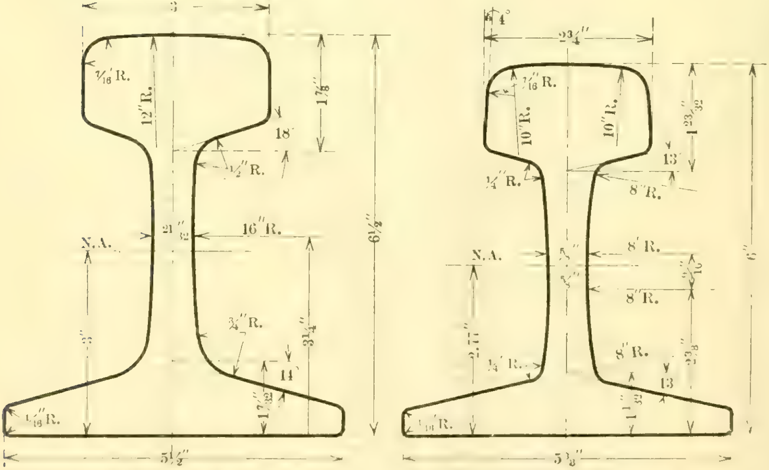
Weight of rail, in pounds per yard.	Year.	Speed, in miles per hour.	MIKADO (2-8-2)																					
			S	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*
85	1915	5	14.3	7.9	— 5.6	— 2.3	14.7	5.8	— 3.5	— 1.4	13.3	5.0	— 4.4	— 1.8	11.4	4.9	— 3.5	— 1.5	14.7	6.4	— 4.7	— 2.0	8.4	7.7
		35	18.1	9.9	— 7.4	— 2.8	17.9	7.1	— 5.5	— 2.1	16.1	6.1	— 6.1	— 2.3	14.7	6.4	— 5.1	— 2.1	18.6	7.8	— 6.6	— 2.6	10.9	9.7
85	1916	5	17.1	9.4	— 6.6	— 2.6	17.7	7.0	— 4.0	— 1.6	16.0	6.1	— 4.7	— 1.9	12.9	5.5	— 3.5	— 1.5	16.1	6.9	— 5.1	— 2.2	10.3	9.1
		35	20.1	11.0	— 7.0	— 2.7	19.4	7.6	— 5.3	— 2.1	16.8	6.4	— 5.3	— 2.1	15.0	6.4	— 5.0	— 2.1	18.9	8.1	— 6.1	— 2.6	12.4	11.0
100	1915	5	12.0	9.6	— 4.2	— 2.5	12.0	6.9	— 2.8	— 1.7	10.8	5.9	— 3.0	— 1.9	10.1	6.2	— 2.6	— 1.7	10.8	6.7	— 3.3	— 2.2	7.2	9.2
		35	14.2	11.3	— 4.8	— 2.7	14.8	8.5	— 4.6	— 2.6	13.4	7.4	— 4.4	— 2.6	12.4	7.7	— 3.7	— 2.3	13.9	8.6	— 4.4	— 2.7	9.7	12.5
125	1915	5	9.8	11.0	— 4.2	3.5	10.1	8.1	— 2.3	— 2.0	9.4	7.3	— 2.7	— 2.4	8.0	7.0	— 2.5	— 2.3	9.4	8.4	— 3.5	— 3.3	5.5	10.0
		35	11.5	13.0	— 6.1	— 5.0	11.6	9.4	— 4.3	— 3.4	11.0	8.7	— 4.4	— 3.6	9.8	8.6	— 4.4	— 3.9	11.1	9.8	— 5.3	— 4.7	7.0	12.8
125	1916	5	10.9	12.3	— 4.2	— 3.4	10.8	8.8	— 3.4	— 2.7	9.7	7.6	— 3.6	— 3.0	8.3	7.3	— 3.2	— 2.8	10.1	8.9	— 3.5	— 3.1	6.6	12.0
		35	13.4	15.1	— 5.1	— 4.1	12.9	10.5	— 4.3	— 3.4	12.4	9.8	— 4.5	— 3.7	10.7	9.4	— 4.5	— 4.0	13.5	11.9	— 4.5	— 4.0	9.5	17.4

SECTIONS OF THE RAILS USED IN TESTS.



85-lb. Am. Soc. C.E. (Worn)

100-lb. Am. Soc. C.E.



125-lb. Penn. R.R.

105-lb. D.L. & W. R. R.

FIG. 107.

factorily than any other form. The variations of the plotted points from the straight lines of the diagrams are generally not greater than may be expected when variations in conditions of track and locomotive, errors of instruments and observations, and other accidental causes of variation are taken into account. Generally, for any test, the lines of a diagram are parallel, or nearly so.

Table 8 gives values of the increase in stress due to speed, as obtained from the rectilinear relation of the diagrams. In the columns marked *A*, the increase is expressed as pound per square inch increase in stress for each mile per hour increase in speed greater than 5 miles per hour. In the columns marked *B*, the effect of speed is given as a percentage of the stress in the rail at 5 miles per hour for each mile per hour increase of speed greater than 5 miles per hour. It will be seen that the values for the increase for positive moment range from about 0.3 to 1.2% increase for each mile per hour increase in speed. Values higher than 0.9% are found in a number of cases.

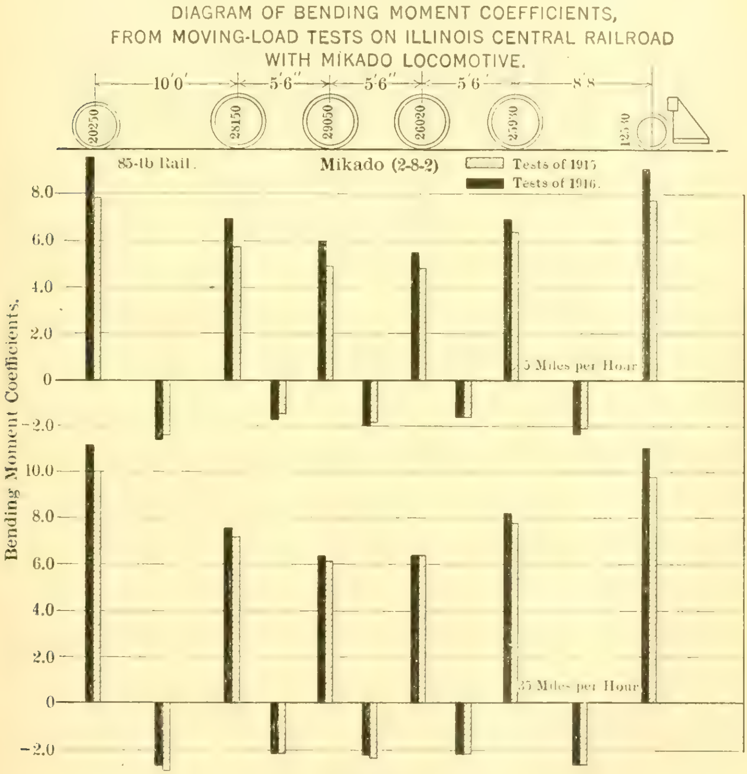


Fig. 108.

The increases found in the tests on the Delaware, Lackawanna and Western Railroad, given in Table 9, are of the same character, but the values are somewhat smaller than those found in the tests on the Illinois Central Railroad.

It will be noted that the effect of speed for the several wheels and for the different rail sections given in the tables shows considerable variation. The cause of these variations is not known. It may be due partly to the track, partly to the locomotives, and partly to accidental conditions of the runs of the tests. Although the runs were all made with the counterweight in its lowest position as it passed the middle instrument, some of the tests were made with the three instruments on the rail at the right side of the locomotive and some with the three instruments at the left side; hence, in one case the counterweights on the other side of the locomotive opposite the three

DIAGRAM OF BENDING MOMENT COEFFICIENTS, FROM MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE.

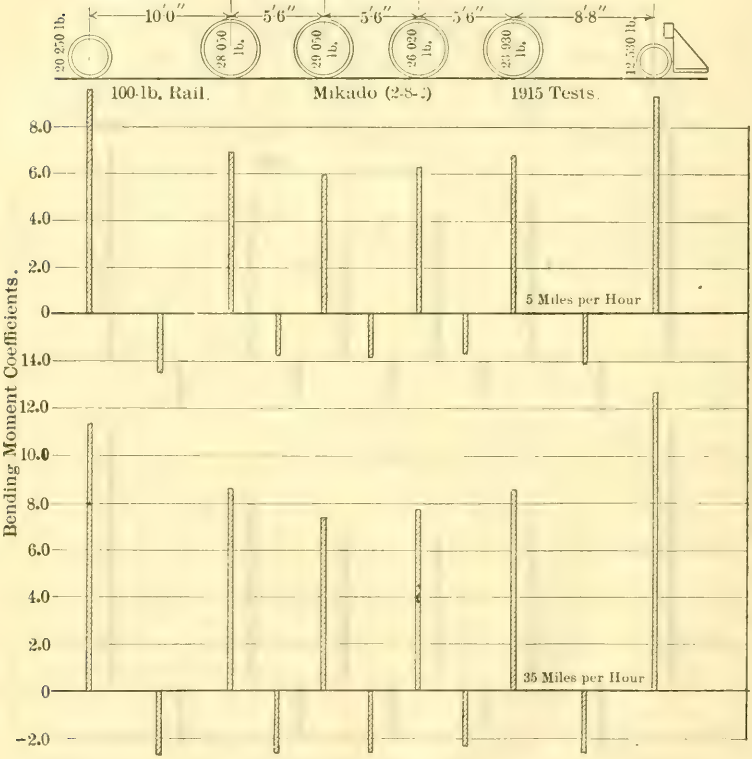


FIG. 109.

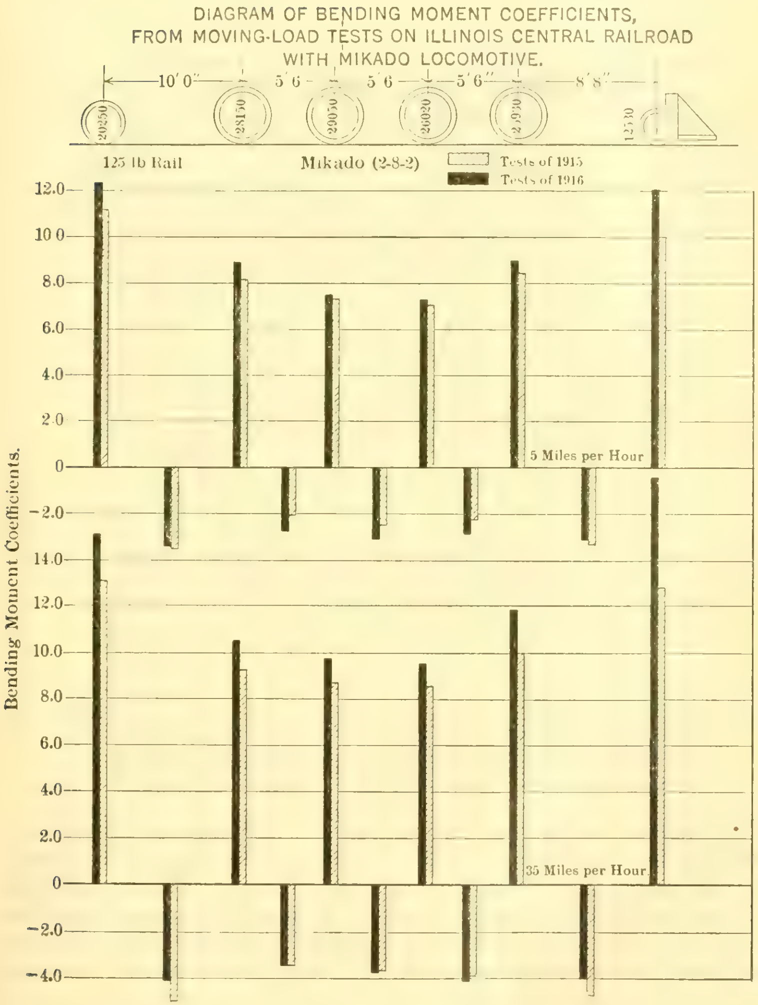
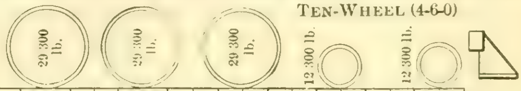


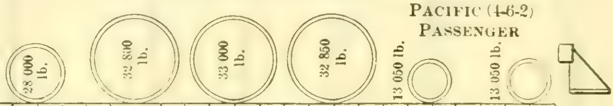
DIAGRAM OF BENDING MOMENT COEFFICIENTS, FROM MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE.

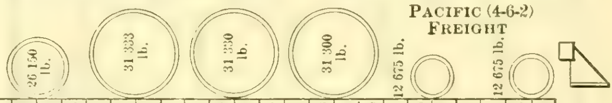
FIG. 110.

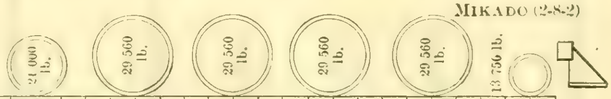
instruments were ahead, and in the other case behind, the position of the middle instrument. A study of the tests shows no variations traceable to these differences of conditions.

TABLE 7.—STRESSES IN RAIL, *S*, AND BENDING MOMENT COEFFICIENTS, *K*, FROM MOVING-LOAD TESTS ON DELAWARE, LACKAWANA AND WESTERN RAILOAD.









Weight of Rail, in Pounds per Yard.	Speed, in miles per hour.																						
		TEN-WHEEL (4-6-0)																					
						S	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*
105	5					14.3	8.4	-4.0	-2.4	14.4	8.5	3.4	-2.0	12.7	7.5	-3.5	-2.1	6.5	9.1	-3.3	-4.6	8.2	11.5
	60					18.3	10.8	-5.0	-2.9	17.7	10.4	-5.2	-3.0	17.7	10.4	-4.8	-2.9	9.8	13.7	-4.9	-6.9	11.0	15.4
		PACIFIC (4-6-2) PASSENGER																					
		S	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*
105	5	14.6	9.0	-5.1	-2.7	13.5	7.1	-4.4	-2.3	12.7	6.6	-4.5	-2.4	13.5	7.1	-3.4	-1.8	5.9	7.8	-3.7	-4.9	7.5	9.9
	60	17.6	10.8	-6.5	-3.8	19.2	9.5	-6.3	-3.3	17.3	9.1	-6.2	-3.2	19.0	10.0	-6.0	-3.1	12.6	16.6	-5.4	-8.5	13.0	17.2
		PACIFIC (4-6-2) FREIGHT																					
		S	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*
105	5	14.2	9.4	4.0	-2.2	15.1	8.3	-3.7	-2.0	14.0	7.7	-3.5	-1.9	12.4	6.8	-3.4	-1.9	6.6	9.0	-3.4	-4.6	8.5	11.5
	50	16.8	11.1	-5.4	-3.0	17.4	9.6	-5.0	-2.8	17.2	9.5	-4.7	-2.6	16.6	9.1	-5.5	-3.0	10.1	13.7	-5.2	-7.0	11.8	16.0
		MIKADO (2-8-2)																					
		S	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*
105	5	[illegible]	9.5	-3.5	-2.0	14.9	8.7	4.2	-2.4	14.1	8.2	-4.5	-2.6	11.6	6.7	[illegible]	-2.2	14.1	8.2	-3.7	-2.2	8.4	10.5
	40	[illegible]	9.7	-6.6	-3.8	16.7	9.7	-5.6	-3.8	16.5	9.6	5.7	3.3	13.6	7.9	-5.0	-2.9	14.7	8.5	-5.5	-3.2	9.9	12.4

The heavier rail section appears to give a somewhat higher proportional increase of stress with increase of speed than the lighter. The indications in the tests on track of the Illinois Central Railroad are that the Mikado locomotive gives a rate of increase somewhat greater than the Atlantic and the Pacific. The tender trucks give a still higher rate of increase, though, of course, the amount of the stress is less than that under the drivers.

The proportional increase in the stress for negative moment is large and rather irregular, as would be expected from the smaller value of this stress and the greater variations of conditions to which it is subjected. The sum of the stresses for positive and negative moment shows greater uniformity in the tests than does either set of stresses.

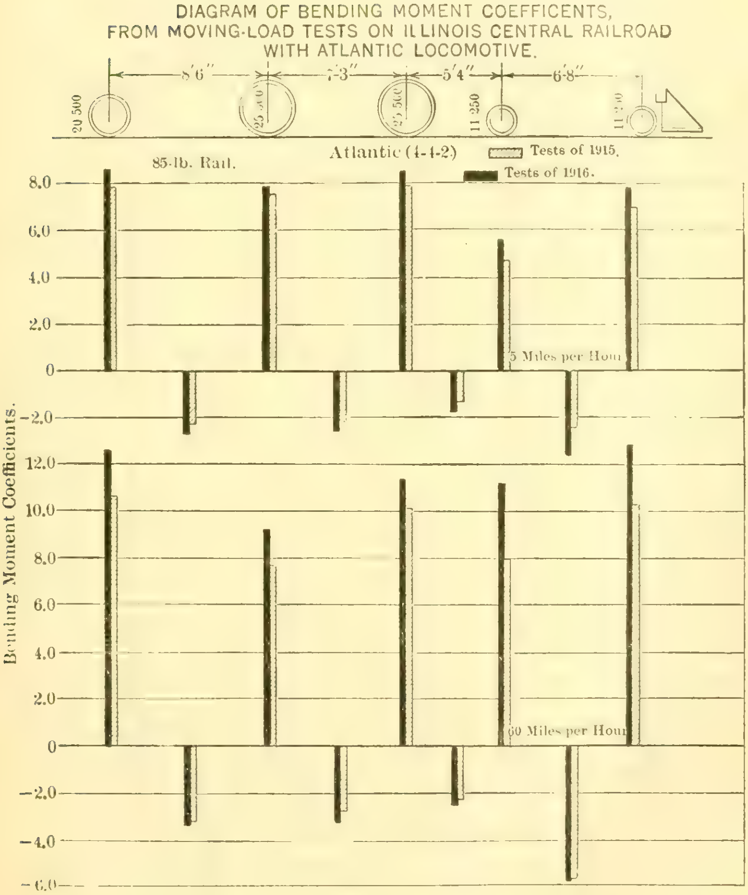


DIAGRAM OF BENDING MOMENT COEFFICENTS,
FROM MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH ATLANTIC LOCOMOTIVE.
8′6″
7′3″
5′4″
6′8″
20 500
25 500
25 500
11 250
11 250
Atlantic (4-4-2)
85-lb. Rail.
Tests of 1915.
Tests of 1916.
Bending Moment Coefficients.
8.0
6.0
4.0
2.0
0
−2.0
5 Miles per Hour
12.0
10.0
8.0
6.0
4.0
2.0
0
−2.0
−4.0
−6.0
60 Miles per Hour

FIG. 111.

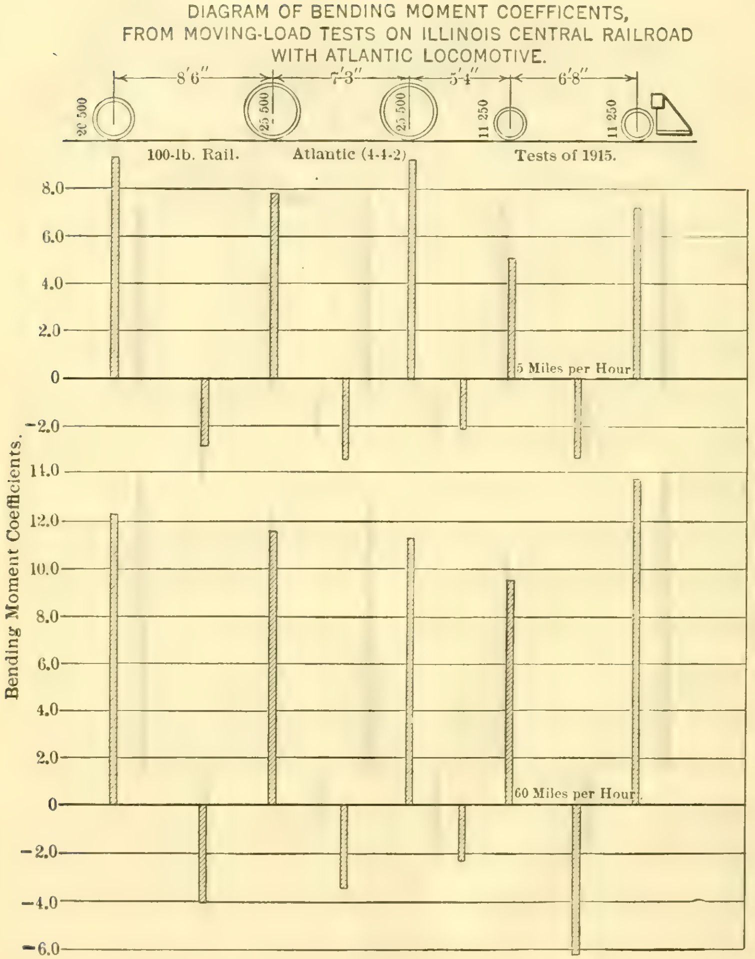


DIAGRAM OF BENDING MOMENT COEFFICENTS,
FROM MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH ATLANTIC LOCOMOTIVE.
8′6″
7′3″
5′4″
6′8″
20 500
25 500
25 500
11 250
11 250
100-lb. Rail.
Atlantic (4-4-2)
Tests of 1915.
Bending Moment Coefficients.
8.0
6.0
4.0
2.0
0
−2.0
5 Miles per Hour
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
−2.0
−4.0
−6.0
60 Miles per Hour

FIG. 112.

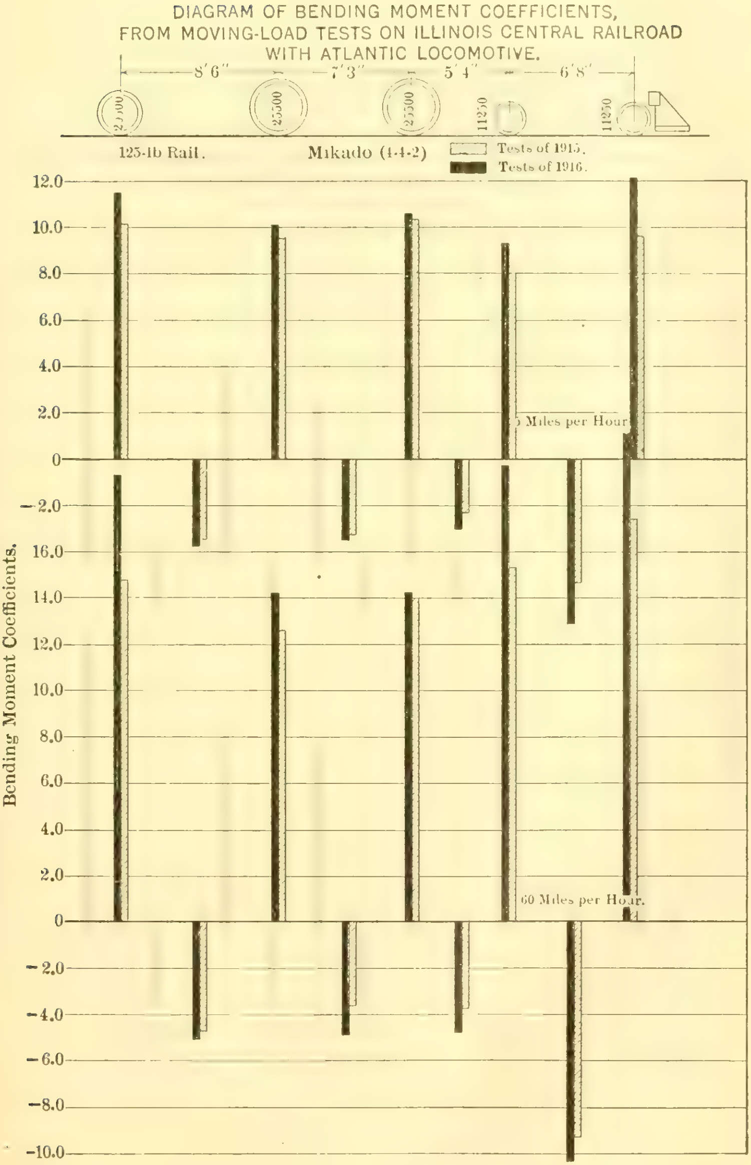


DIAGRAM OF BENDING MOMENT COEFFICIENTS,
FROM MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH ATLANTIC LOCOMOTIVE.
8′6″
7′3″
5′4″
6′8″
25500
25500
11250
11250
125-lb Rail.
Mikado (4-4-2)
Tests of 1915.
Tests of 1916.
12.0
10.0
8.0
6.0
4.0
2.0
0
−2.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
−2.0
−4.0
−6.0
−8.0
−10.0
Bending Moment Coefficients.
5 Miles per Hour
60 Miles per Hour.

FIG. 113.

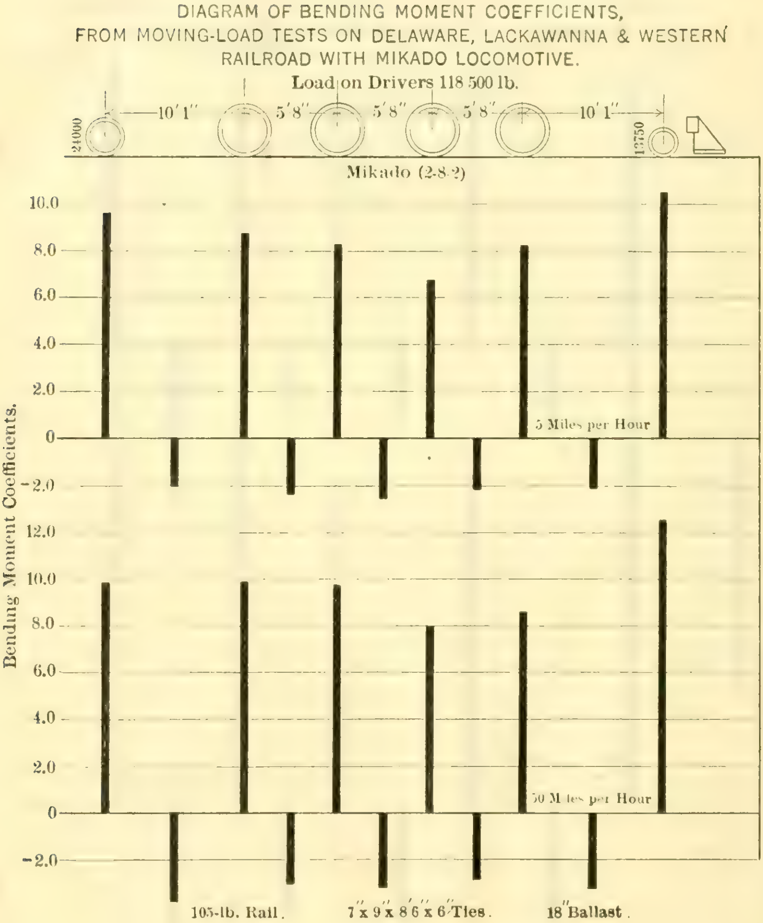


DIAGRAM OF BENDING MOMENT COEFFICIENTS,
FROM MOVING-LOAD TESTS ON DELAWARE, LACKAWANNA & WESTERN RAILROAD WITH MIKADO LOCOMOTIVE.
Load on Drivers 118 500 lb.
24000
10′ 1″
5′ 8″
5′ 8″
5′ 8″
10′ 1″
13750
Mikado (2-8-2)
Bending Moment Coefficients.
10.0
8.0
6.0
4.0
2.0
0
-2.0
5 Miles per Hour
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
50 Miles per Hour
105-lb. Rail.
7″ x 9″ x 8′ 6″ x 6″ Ties.
18″ Ballast.

FIG. 114.

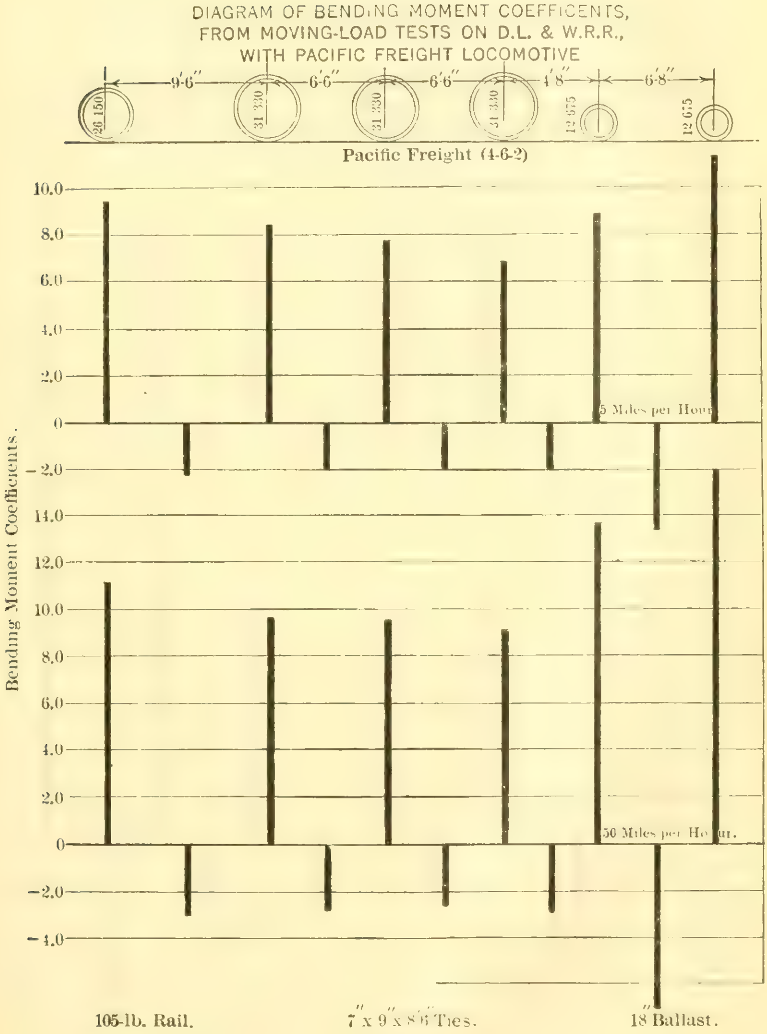


DIAGRAM OF BENDING MOMENT COEFFICENTS,
FROM MOVING-LOAD TESTS ON D.L. & W.R.R.,
WITH PACIFIC FREIGHT LOCOMOTIVE
9'6"
6'6"
6'6"
4'8"
6'8"
26 150
31 330
31 330
31 330
12 675
12 675
Pacific Freight (4-6-2)
Bending Moment Coefficients.
10.0
8.0
6.0
4.0
2.0
0
−2.0
5 Miles per Hour
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
−2.0
−4.0
50 Miles per Hour.
105-lb. Rail.
7" x 9" x 8'6" Ties.
18" Ballast.

Fig. 115.

DIAGRAM OF BENDING MOMENT COEFFICIENTS,
FROM MOVING-LOAD TESTS ON D. L. & W. R.R.,
WITH PACIFIC PASSENGER LOCOMOTIVE.

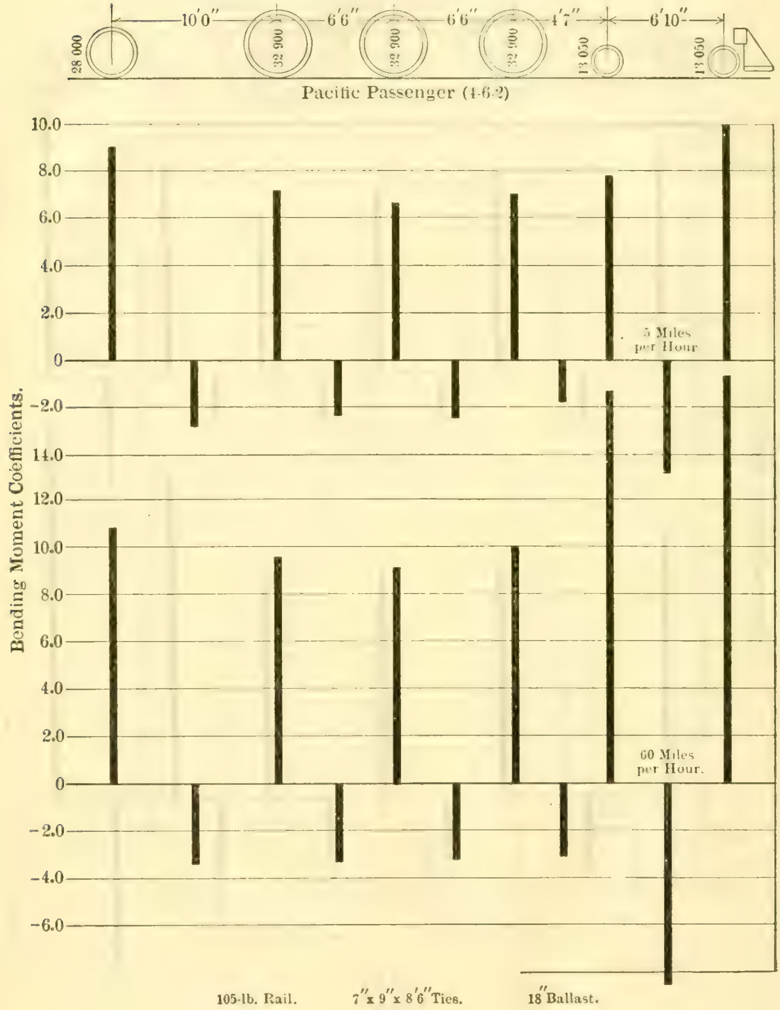
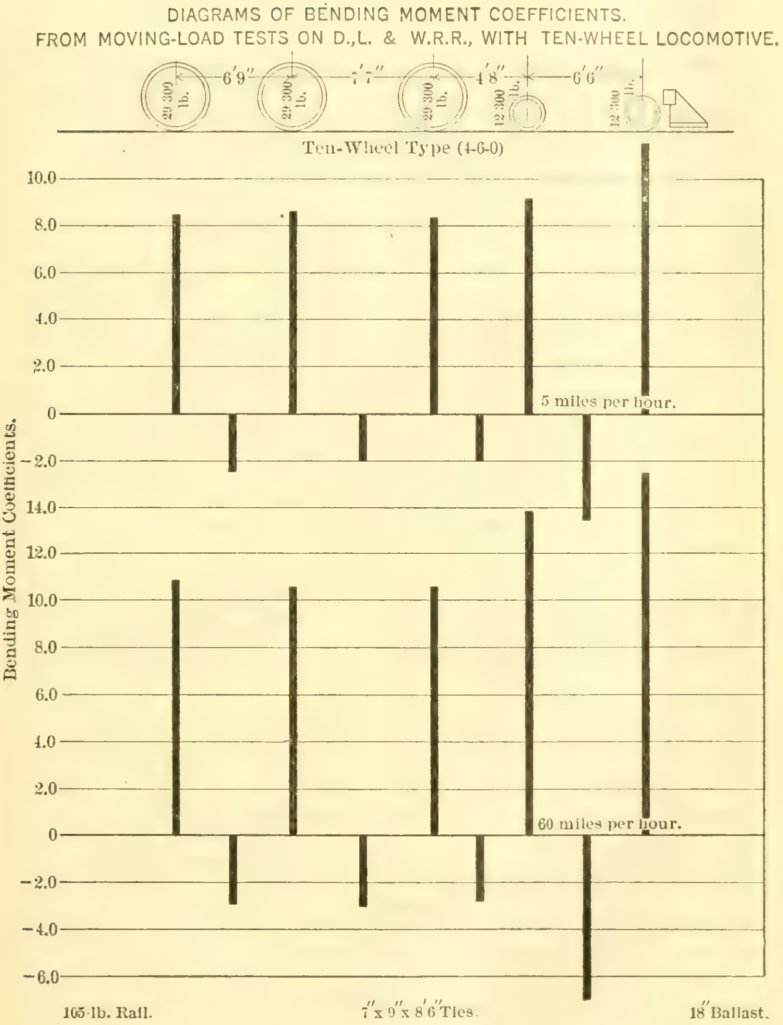


FIG. 116.



DIAGRAMS OF BENDING MOMENT COEFFICIENTS.
FROM MOVING-LOAD TESTS ON D.,L. & W.R.R., WITH TEN-WHEEL LOCOMOTIVE.

Fig. 117.

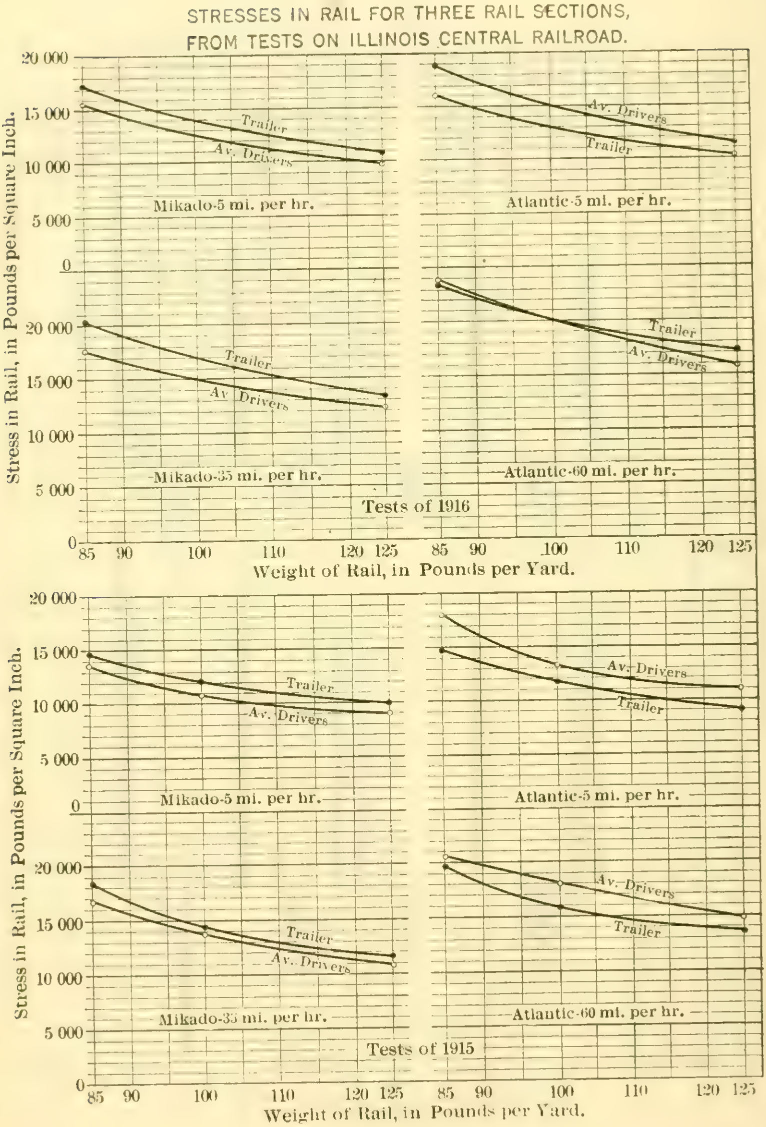
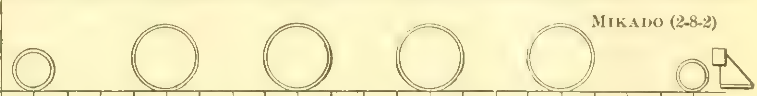

STRESSES IN RAIL FOR THREE RAIL SECTIONS,
FROM TESTS ON ILLINOIS CENTRAL RAILROAD.
Stress in Rail, in Pounds per Square Inch.
20 000
15 000
10 000
5 000
0
Trailer
Av. Drivers
Mikado-5 mi. per hr.
Atlantic-5 mi. per hr.
Mikado-35 mi. per hr.
Atlantic-60 mi. per hr.
Tests of 1916
Tests of 1915
85
90
100
110
120
125
Weight of Rail, in Pounds per Yard.

FIG. 118.

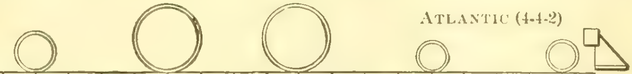
TABLE 8.—INCREASE IN STRESS IN RAIL DUE TO SPEED. TESTS ON ILLINOIS CENTRAL RAILROAD.

MIKADO (2-8-2)



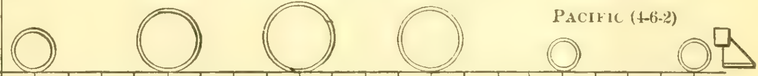
Weight of Rail, in Pounds per Yard.	Year.	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
85	1915	132	0.93	53	0.98	120	0.82	56	1.73	96	0.77	53	1.30	120	1.10	.53	1.60	107	0.74	60	1.28	81	0.95
85	1916	108	0.64	24	0.45	78	0.44	3.9	0.95	29	0.18	21	0.42	81	0.59	41	1.30	72	0.44	39	0.77	80	0.73
100	1915	75	0.63	21	0.51	93	0.78	48	1.90	94	0.88	45	1.50	77	0.77	38	1.50	102	0.95	38	1.20	85	1.20
125	1915	57	0.51	62	1.50	50	0.49	67	2.90	55	0.58	57	2.10	62	0.77	62	2.40	55	0.58	59	1.70	54	0.98
125	1916	85	0.78	32	0.87	70	0.65	28	0.83	90	0.92	30	1.00	78	0.94	43	1.10	115	1.20	35	1.20	95	1.50

ATLANTIC (4-4-2)



		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
85	1915	96	0.65	30	0.59	53	0.29	32	0.76	53	0.30	40	1.40	94	2.10	63	1.30	93	1.30
85	1916	133	0.84	25	0.45	59	0.33	32	0.65	119	0.61	34	0.91	104	2	41	1.20	95	1.20
100	1915	71	0.60	40	0.93	116	0.86	5	0.11	58	0.40	9	0.32	55	1.50	40	1.80	82	1.60
125	1915	82	0.90	31	0.84	62	0.59	13	0.42	73	0.63	31	1.20	66	1.70	38	1.50	69	1.50
125	1916	124	1.20	28	0.71	82	0.72	27	0.71	75	0.63	35	1.10	95	2.10	29	0.88	80	1.30

PACIFIC (4-6-2)



		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
85	1915	66	0.43	47	0.89	58	0.40	6	0.12	60	0.43	13	0.30	66	0.50	36	1.40	53	0.68	27	0.75	28	0.35
125	1916	73	0.65	- 2	-0.04	62	0.61	5.5	0.12	57	0.52	11	0.23	86	0.84	35	0.91	118	2.30	24	0.47	100	1.60

Exceptions from uniformity of action are found in the tests. In Fig. 82, the stresses under the rear driver are less at high speeds than at low speeds, and the data at the several speeds are consistent. In other instances, one driver or one truck wheel shows a much higher increase with speed than do the other wheels.

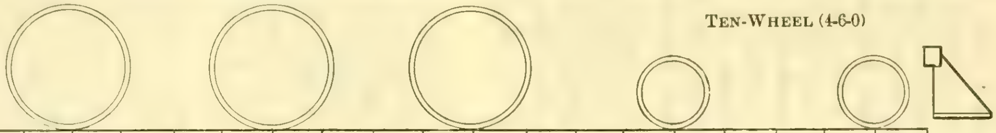
It should be remembered that the diagrams and tests give the average of a large number of runs, and, of course, the increases found for individual runs are considerably greater than the average values.

No discussion of the cause of the increased stress at the higher speeds will be made at the present time.

50.—Influence of Rail Section.—In structural members, the bending moment for a given load is usually independent of the section of a beam or girder which carries load, and the fiber stress in the beam is inversely proportional to the section modulus, $\frac{I}{c}$. For the track structure, it has been shown by analysis that, for a one-axle load,

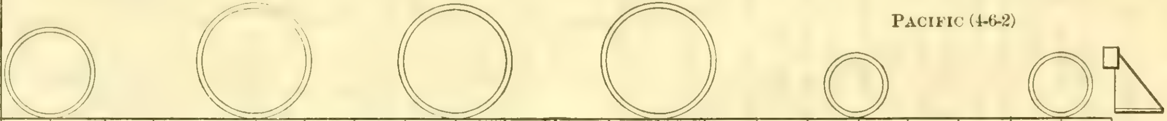
TABLE 9.—Increase in Stress in Rail Due to Speed.
Tests on Delaware, Lackawanna and Western Railroad.

Ten-Wheel (4-6-0)



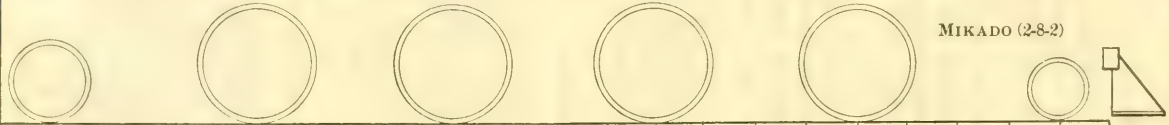
Weight of Rail, in Pounds per Yard.																						
			A	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*		
105			73	0.51	18	0.45	60	0.42	33	0.97	91	0.72	24	0.67	60	0.92	29	0.88	51	0.62		

Pacific (4-6-2)



Weight of Rail, in Pounds per Yard.																							
	A	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	
105	55	0.37	25	0.50	86	0.63	35	0.79	84	0.66	31	0.69	98	0.72	47	1.39	122	2.06	49	1.33	100	1.33	Pass.
105	58	0.41	31	0.78	51	0.34	29	0.78	71	0.51	27	0.76	93	0.75	47	1.37	78	1.18	40	1.18	73	0.86	Frt.

Mikado (2-8-2)



Weight of Rail, in Pounds per Yard.																						
	A	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*
105	9	0.65	89	2.53	52	0.35	40	0.95	69	0.49	31	0.76	57	0.49	34	0.90	17	1.21	52	1.39	43	0.51

the bending moment developed varies with the rail section, becoming larger as the moment of inertia of the section is increased; and, therefore, in calculating the fiber stress produced by a given load in a given rail section, the value of the bending moment developed with the use of that rail section must be known. For a two-axle or a three-axle load, or for a combination of driver loads and truck wheel loads, the magnitude of the bending moment will still be dependent on the rail section, but not to the same extent as with a single load; and the influence of the rail section on the bending moment developed will also depend on the wheel spacing. The general analytical relations involving the effect of the rail section on the bending moment have already been derived. Values found from the tests will now be presented. It will be most convenient to use in the discussion the bending moment coefficient, K, by which the wheel load, P, may be multiplied to get the bending moment at the load or at a point between loads.

The results are presented graphically, the values of the bending moment coefficients obtained at the drivers and other loads being plotted against the moment of inertia of the rail section. Fig. 119 gives the values from the tests on the Illinois Central Railroad for one-axle and two-axle loads applied statically and for three types of locomotive at two speeds. The values at the left of each diagram, plotted for a moment of inertia of 27, are results obtained with the worn 85-lb. rail (see Table 5 for properties of the rail sections). The values at the right of each diagram, plotted for a moment of inertia of 68.7, are results obtained with the 125-lb. rail. In the case of the one-axle and two-axle loads, results are also given for the 100-lb. rail, the moment of inertia of the section being 44. The moving-load tests with the Mikado and Atlantic locomotives on the 100-lb. rail were made in 1915, and, therefore, with the old form of stremmatograph; the tests with the 85-lb. and 125-lb. rails, the results of which are plotted on Fig. 119, were made in 1916 with the new form of stremmatograph. For this reason, the tests with the Mikado and Atlantic locomotives on the 100-lb. rail are not plotted. Only 1915 tests are available for the Pacific locomotive and the 85-lb. rail; in comparing with the bending moment coefficients for the 125-lb. rail from the 1916 tests, it should be kept in mind that the 1915 values are probably somewhat low. For convenience in comparing results, lines have been drawn connecting corresponding points.

The upper left diagram of Fig. 119 gives values of the bending moment coefficient for the one-axle load tests with the three rail sections. In the static-load tests as readings were taken on only one side of the rail, except in the 1917 tests, the values may not be directly comparable, though, for this form of test, not much variation has been found for the two sides of the rail. It is seen that the heavier rail gives a much higher bending moment coefficient than the lighter.

If the difference in the track conditions is taken into account, the 125-lb. rail being on track with 24-in. ballast, which gave a higher modulus of elasticity of rail-support than that of the track on which the tests of 85-lb. rail here used were made, the contrast becomes greater. Fig. 119 also gives the analytical values of the bending moment coefficients for a one-axle load based on the probable values of the modulus of elasticity of rail-support used in the tests, 1 000 in one case and 1 600 in the other. The trend of the analytical values is much the same as that derived from the test data.

The upper right diagram of Fig. 119 gives values of the bending moment coefficient corresponding to the observed stress found in the three rail sections for the two-axle load tests. The wheel spacing is 66 in. The analytical values of the bending moment coefficients are also given. The same values of the modulus of elasticity of rail-support are used as for the one-axle load tests. The trend of the values shows higher bending moment coefficients for the heavier rail sections.

Fig. 119 also gives values of the bending moment coefficients corresponding to the stresses observed in the moving-load tests with the Mikado, Atlantic, and Pacific locomotives. Values are given for speeds of 5 and 35 or 60 miles per hour. The bending moment coefficients for the heavier rail sections are markedly larger than for the lighter sections, and this is true for the drivers and the trailer. The values of the coefficients of negative bending moment are not plotted here, but these also show an increased coefficient for the heavier rail sections. That the bending moment coefficients should be greater for the heavier sections is evident from analytical considerations, especially in the case of the trailer, which is at some distance from other wheels, and in the case of outer drivers. The increase due to increase of section, however, is greater than may be expected from the analysis of track action herein given, or for any known rational analysis. For the drivers and trailer of the three types of locomotive used on the Illinois Central Railroad, the values of the bending moment coefficient derived by the analysis are less than 10% higher for track with the 125-lb. than for track with the 85-lb. section. For the tests at 5 miles per hour, the values of the bending moment coefficients average nearly 30% higher with the 125-lb. than with the 85-lb. section, considering the drivers and the trailer of the three types of locomotive. For the tests at the higher speeds, the increase is still greater.

On Fig. 119 also are plotted points for the bending moment coefficients derived from the tests on the Delaware, Lackawanna and Western Railroad with the Mikado and Pacific locomotives, the rail being 105-lb. section. The wheel spacing and wheel loads in these locomotives are, of course, not the same as those of the same type on the Illinois Central Railroad.

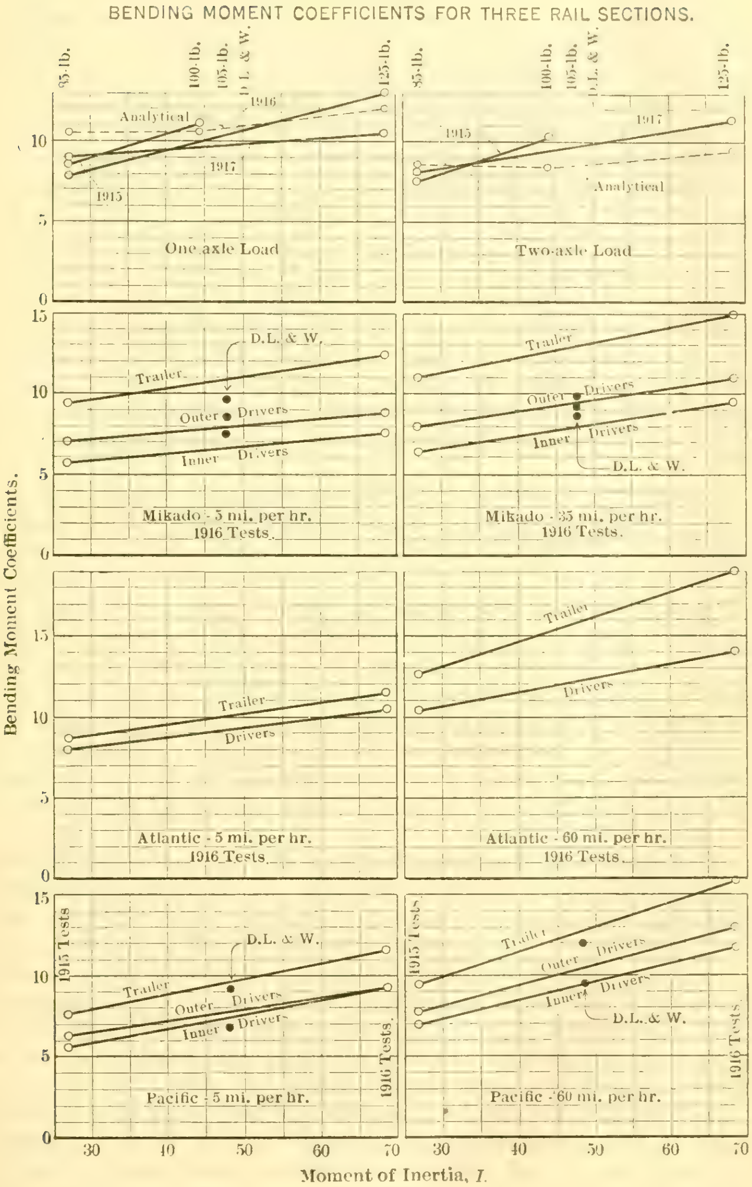

BENDING MOMENT COEFFICIENTS FOR THREE RAIL SECTIONS.
85-lb.
100-lb.
105-lb.
D.L. & W.
125-lb.
Analytical
1916
1915
1917
One axle Load
Two-axle Load
Trailer
Outer Drivers
Inner Drivers
D.L. & W.
Mikado - 5 mi. per hr. 1916 Tests.
Mikado - 35 mi. per hr. 1916 Tests.
Drivers
Atlantic - 5 mi. per hr. 1916 Tests.
Atlantic - 60 mi. per hr. 1916 Tests.
1915 Tests
1916 Tests.
Pacific - 5 mi. per hr.
Pacific - 60 mi. per hr.
Bending Moment Coefficients.
0
5
10
15
30
40
50
60
70
Moment of Inertia, I.

FIG. 119.

51.—Effect of Wheel Spacing.—The analytical treatment of the action of track showed that the spacing of wheels has a considerable effect on the magnitude of the bending moments developed in the rail. The experimental values confirm this finding. An inspection of Fig. 119 shows that, for all the locomotives except the Atlantic, the bending moment coefficients for the trailers, which are well away from the drivers and the tender trucks, are considerably higher than those for the drivers, and that those for the drivers of the Atlantic locomotive are higher than for the more closely spaced drivers of the Mikado locomotive. The effect is even more marked at the higher speeds. Another view of this may be had from the stresses plotted in Fig. 118. Notwithstanding that the weight on the trailers of these locomotives is only from 75 to 80% of that on a driver, the stresses in the rail under the trailer are greater than those under the drivers, except for the Atlantic locomotive, and in that case there is greater spacing of drivers and smaller distance from rear driver to trailer. All the results confirm the importance of wheel spacing indicated by the analysis.

Something of the effect of changing the spacing of wheels is shown by Figs. 120, 121, and 122, where values of the bending moment coefficients derived by the analytical method are plotted against wheel spacing for two-axle, three-axle, and four-axle loads. In some cases it is seen that there are regions of spacing where the spacing has little effect on the bending moment coefficient. It is to be noted that, for a point midway between wheels, the shorter spacings give positive moments. Although the values given in this figure will not correspond exactly with experimental results, the figure is useful in learning the trend of the effect of changes in wheel spacing. It is evident that the effect of wheel spacing on stresses in track is a matter which should have consideration when the design of the spacing of the wheels of locomotives and cars is made.

52.—Influence of Condition of Track and Locomotive.—The tests already reported are mainly on the prepared test sections of track, which were laid with new oak ties of uniform size and shape, uniformly spaced, and kept in excellent surface condition. It was felt that some connection of results should be made with track in conditions other than those of the prepared track, and tests were made on what may be considered the ordinary run of main-line track adjoining the test sections and on track having special conditions, such as low spots, defective ties, and cinder ballast.

The tests on what may be termed the ordinary track of the Illinois Central Railroad were made on track adjacent to the test sections. The conditions of rail, ballast, and roadway were quite similar to those of the prepared test sections. The ties were sound hewn ties of mixed woods, oak and gum, and some pine, nominally 6 by 8 in.

BENDING MOMENT COEFFICIENTS FOR TWO-AXLE LOAD, FROM ANALYSIS.

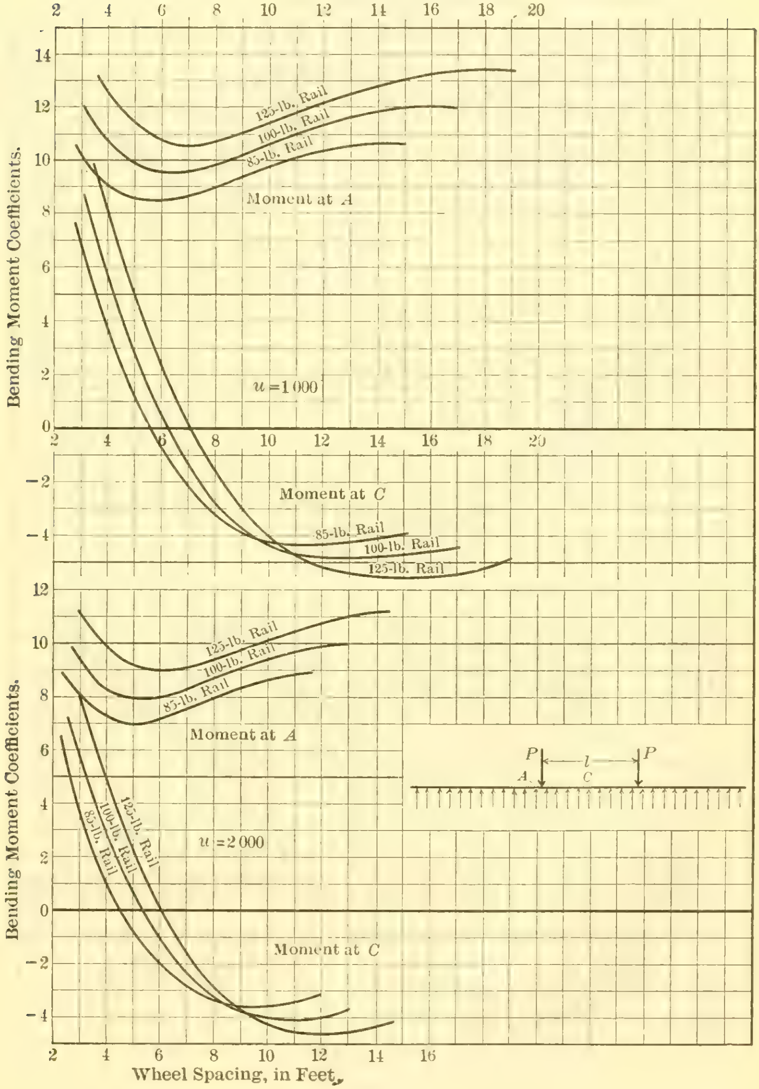


FIG. 120.

BENDING MOMENT COEFFICIENTS FOR THREE-AXLE LOAD, FROM ANALYSIS.

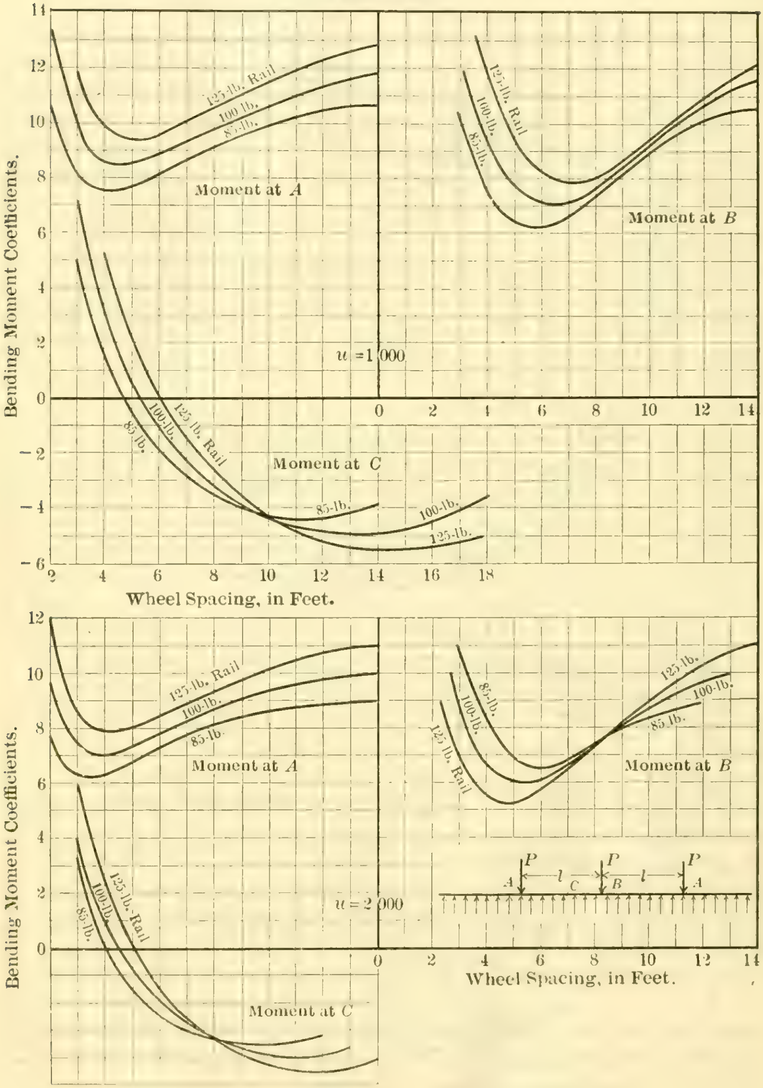


FIG. 121.

BENDING MOMENT COEFFICIENTS FOR FOUR-AXLE LOAD FROM ANALYSIS.

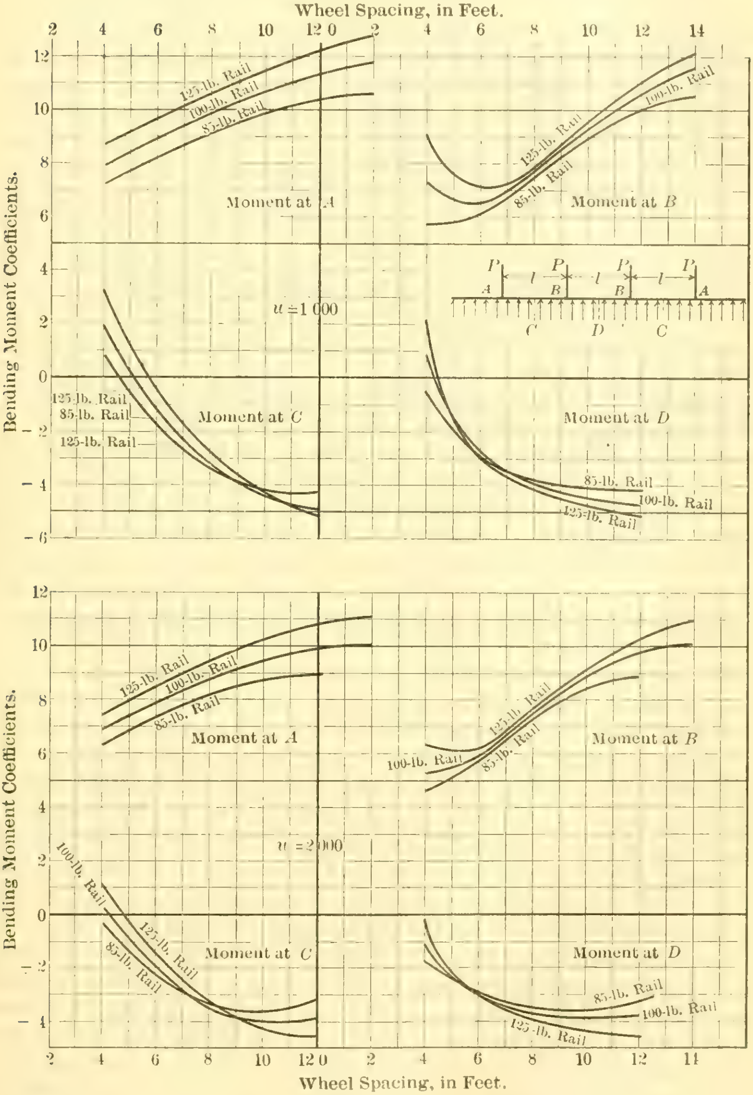


FIG. 122.

by 8 ft., the spacing being fairly uniform, and about 20 in. from center to center. The tests were made on stretches of track having 6 and 24 in. of ballast under the ties. The track was in good condition. Fig. 123 gives track depression profiles for one-axle load tests at three locations. The data were obtained photographically, and cover only a short length of track for each location. Fig. 124 shows the stress-distribution diagrams at the same places, and Fig. 125 gives load-stress diagrams. It will be noted that the load-stress diagrams approximate straight lines passing through the origin. Figs. 126 and 127 give speed-stress diagrams for locomotive loading at several speeds at two places along the track. The position of the instruments and the methods used were the same as in the tests reported for the test track. The average value of the modulus of elasticity of rail-support, u, taken from the one-axle load tests, is about 1 000, which is about the same as the average for the special test sections (omitting the 24-in. ballast). The stresses in rail, both for the one-axle and the moving-load tests, agree closely with the results found in the similar tests on the prepared test stretches of track of like conditions of ballast and rail, the differences being no more than may be due to accidental differences in the locomotives or to accidental differences in testing. The results indicate that the tests on the prepared sections of track may be taken as representative of similar track under ordinarily good conditions, and that the principal difference to be expected in ordinary track is a greater variation in results and somewhat larger individual values where differences in tamping, or in size, quality, or spacing of tie, may result in a greater variation from the average stress.

To get some indication of the effect of a poor tie, tests were made in several places where a tie under one rail was decayed somewhat, and the rail had cut into the adjoining ties, the decayed tie not taking its full share of load, and the adjoining ties having more than their share. Fig. 128 gives track depression profiles for the one-axle load tests at three locations, *E, F,* and *G* of Fig. 26, the load being placed over the decayed tie. The profiles are characterized by a sharper curvature at the point under the load than was found in the tests with sound ties, though the depression was not particularly greater than in ordinary track. Fig. 129 shows the stress-distribution diagrams at the same places, and Fig. 130 gives load-stress diagrams. In some cases the load-stress diagram is a straight line passing through the origin, and in some cases not. The stresses in the rail over the decayed tie for a single wheel load of 25 000 lb. are 23 800, 25 600, and 29 200 lb. per sq. in. (averaging 26 200 lb. per sq. in.), which may be compared with an average stress of about 21 000 lb. per sq. in. for otherwise like conditions of track in the prepared test sections. Moving-load tests with the Mikado locomotive were also

TRACK DEPRESSION PROFILES FOR ORDINARY TRACK.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD,
WITH LOADING APPARATUS.

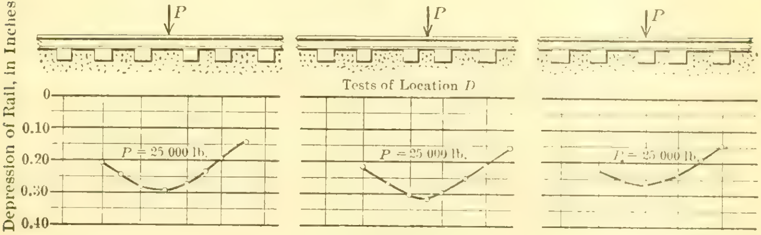


FIG. 123.

STRESS DISTRIBUTION DIAGRAMS FOR ORDINARY TRACK.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD,
WITH LOADING APPARATUS.

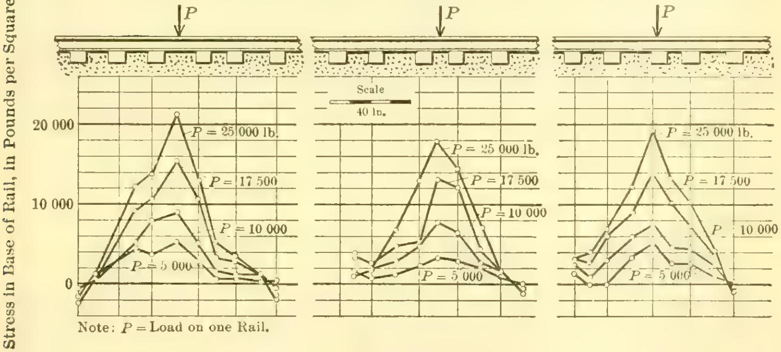
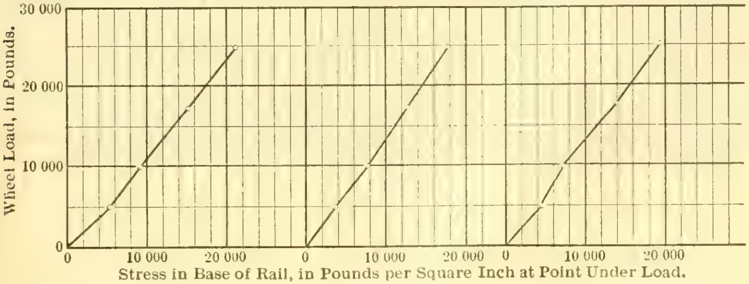


FIG. 124.

LOAD-STRESS DIAGRAMS FOR ORDINARY TRACK.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD, WITH LOADING APPARATUS.



ONE-AXLE LOAD

85-lb. Rail. 6" x 8" x 8' Ties About 6" Stone Ballast.

FIG. 125.

SPEED-STRESS DIAGRAMS FOR ORDINARY TRACK
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE.

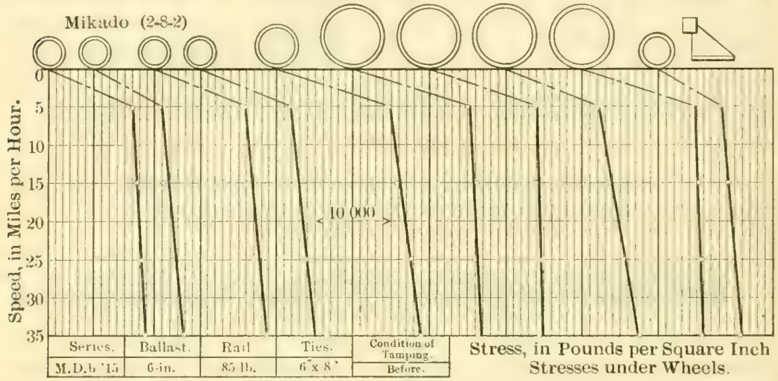


FIG. 126–a.

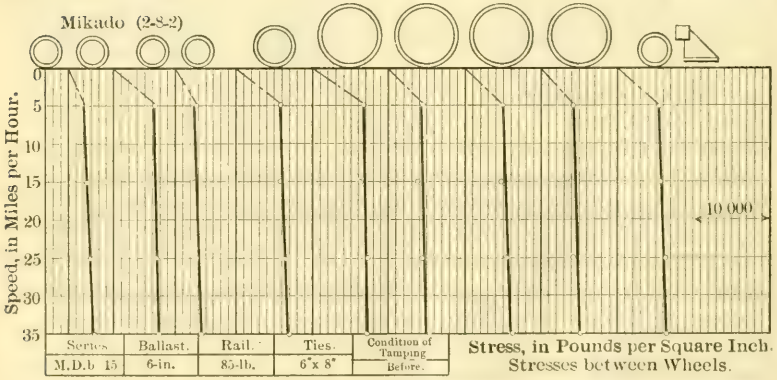


FIG. 126–b.

SPEED-STRESS DIAGRAMS FOR ORDINARY TRACK
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE.

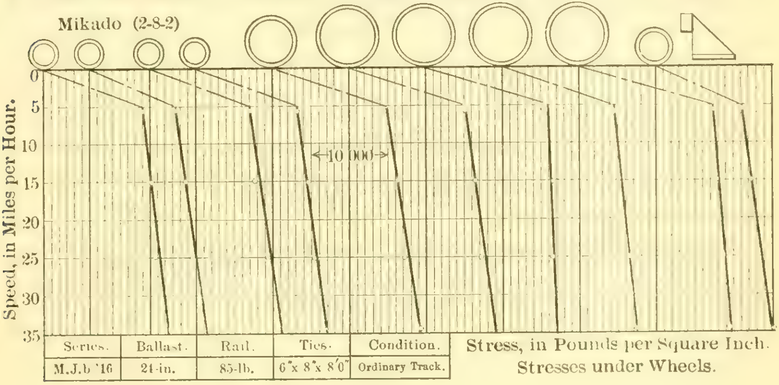


FIG. 127–a.

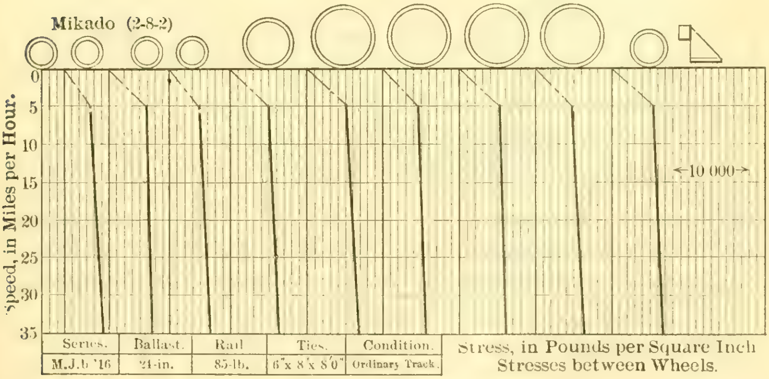


FIG. 127–b.

TRACK DEPRESSION PROFILES FOR DECAYED TIE.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD, WITH LOADING APPARATUS.

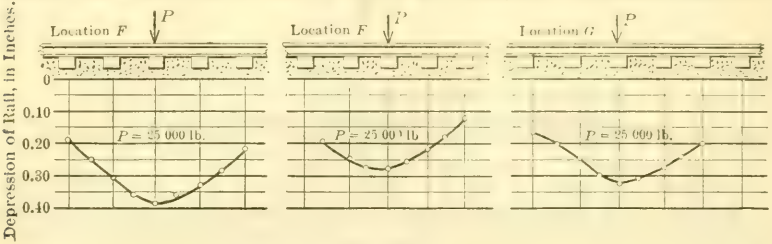
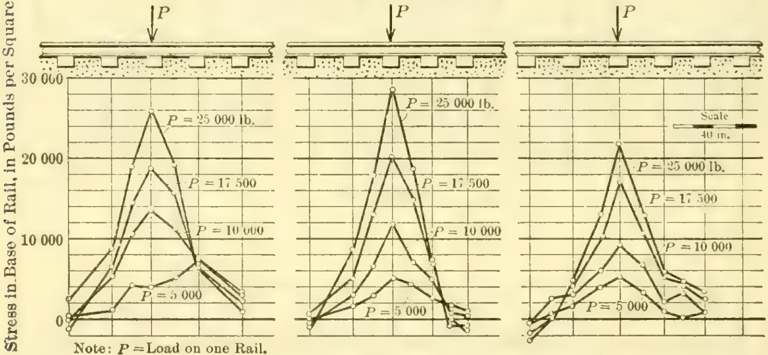


FIG. 128.

STRESS DISTRIBUTION DIAGRAMS FOR DECAYED TIE.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD,
WITH LOADING APPARATUS.



Note: P = Load on one Rail.

FIG. 129.

LOAD-STRESS DIAGRAMS FOR DECAYED TIE.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD, WITH LOADING APPARATUS.

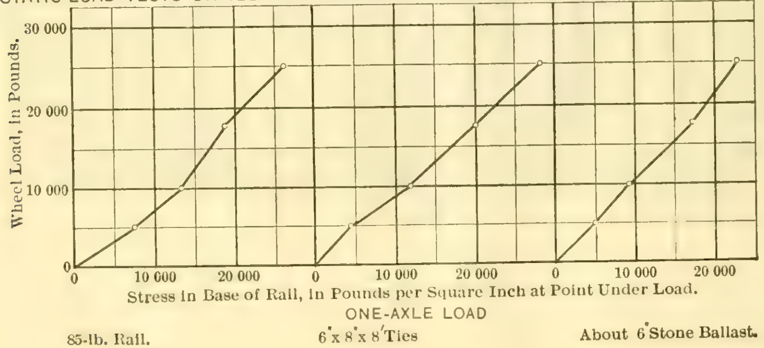


FIG. 130.

made at the two locations, *I* and *L*, shown on Fig. 26. Fig. 131 gives the position of the instruments with reference to the decayed tie, and Figs. 132 and 133 are speed-stress diagrams giving the average of the stresses obtained with three instruments. At *I*, the decayed tie was in such condition that it gave little bearing resistance to the rail load, and the two adjoining ties were sound, but somewhat cut by the rail. At *L*, the decayed tie offered some bearing resistance, but the adjacent ties were poor and badly cut. Comparing the stresses in the rail given in these figures with the average stresses for the prepared test sections, it is seen that the stresses under the drivers and trailer of the Mikado locomotive at the several speeds from 5 to 35 miles per hour average about 20% higher in the first location and from 35 to 40% higher in the second. As these stresses were measured

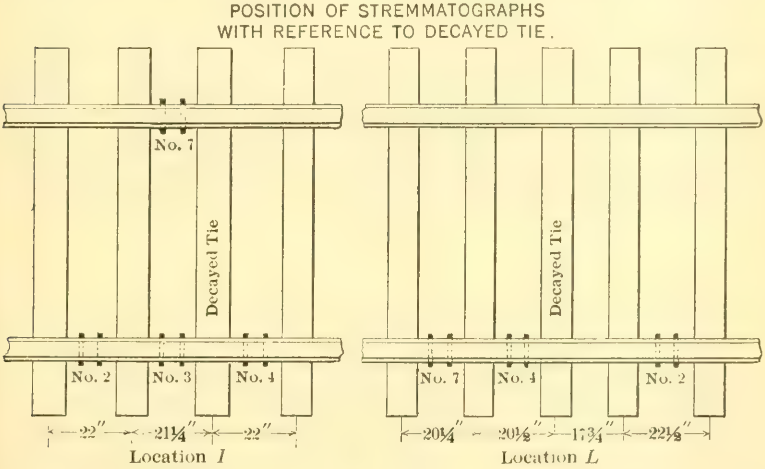


FIG. 131.

at gauge lines between ties, and include measurements made at places away from the decayed tie, it may be expected that the stress in the rail at a point over the decayed tie would be materially higher than that given in the diagrams. It will be shown in the next article that the variation in stress on the two sides of the rail is much greater in this case than in ordinarily good track. Stresses at the outer edge of base of rail were found which average about 150% higher than the average rail stress for good track.

Tests were made on a spot where, for about a rail length, the track was low, especially along one rail. A low spot on the other rail, a rail length or so away, served to give the locomotive a roll at speeds greater than 5 miles per hour. The sags were quite apparent to the eye. The section foreman explained the presence of the low spots as caused by

SPEED-STRESS DIAGRAMS FOR DECAYED TIE.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE.

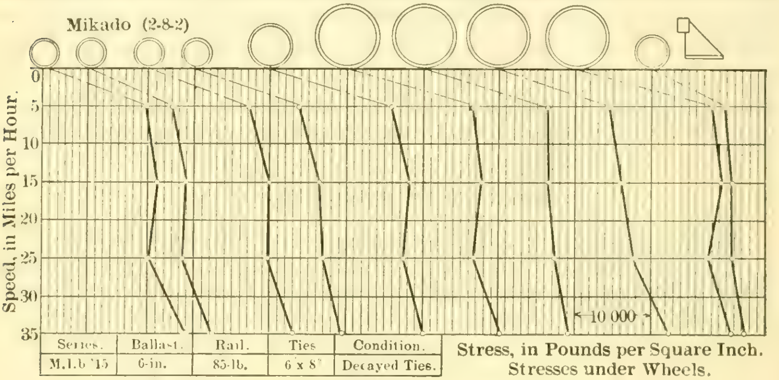


FIG. 132–a.

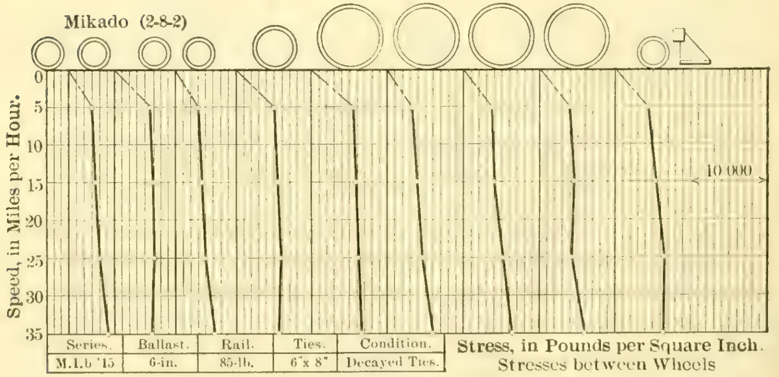


FIG. 132 b.

SPEED-STRESS DIAGRAMS FOR DECAYED TIE.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE.

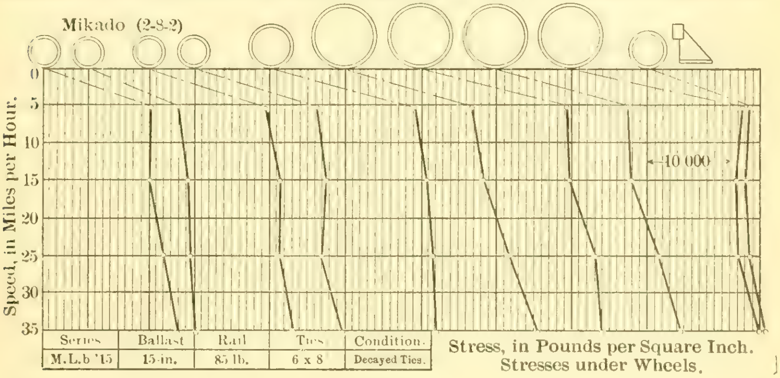


FIG. 133–a.

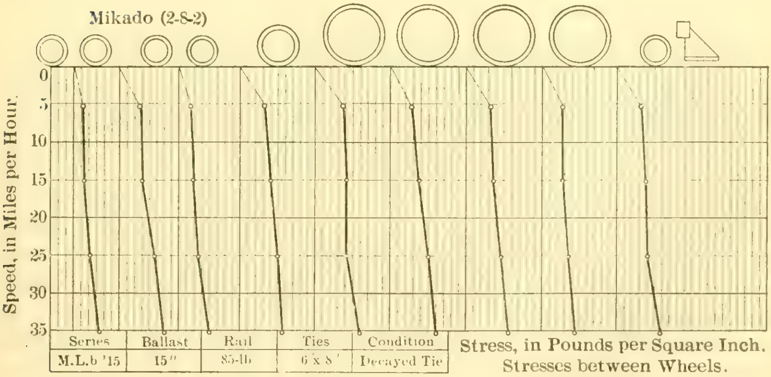


FIG. 133–b.

too much tamping at the ends of the rail in raising the joints which had become low. The track depression throughout the middle of the length of the rail under the static-load tests was 0.70 in. under the rear driver of the Atlantic locomotive, about double that found after the track had been properly tamped up, the latter being about the same as that which was found in ordinarily good track. Figs. 134 to 136 give the speed-stress diagrams for the Atlantic locomotive at this low spot. The number of observations is smaller than those averaged in the tests on the prepared stretches of track, but it is large enough to seem to be representative of the action of the track here. At 5 miles per hour the stress in rail is about 15% higher than for good track, and, at 60 miles per hour, from 20 to 35% higher. At the latter speed, values at the front driver were found as high as 43% more than for good track. In each case the values plotted are the averages of those obtained with the three instruments on the low rail for three or more runs.

Tests were made on the track which leads from the freight yards at *N*, in Fig. 26. This track has 6 in. of cinder ballast on a light loam soil. The ties were in good condition and the tie spacing uniform. Although not recently tamped, the track was in fair condition. Fig. 137 gives the speed-stress diagrams for the Mikado locomotive. The stresses are higher than those found with 6 in. of ballast on the main-line track, averaging, perhaps, 12% higher, and under some wheels being 18% or more higher. A rather marked characteristic of these diagrams is the unusual variation in values at the different wheels and the different speeds; individual results are found which are much higher than the average values plotted in the diagrams.

Although this report will not take up the observed action of the ties and ballast, and the relation of their properties to the properties of the track, it may be remarked here that the prepared main-line test track, which is ballasted with broken stone, seems to show little difference between the stresses in rail on track which has 6 in. of ballast and on track which has 12 in. The results are more erratic and more variable in the former case than in the latter, and, of course, the question of the time intervals between necessary track surfacing is not here considered. The track with 24-in. ballast was noticeably stiffer than either of the foregoing, giving smaller track depressions under load and a larger value of the modulus of elasticity of rail-support. The diagrams also show that the track on 24-in. ballast has somewhat smaller stress in the rail than that on lighter ballast.

To show that conditions of the locomotive may greatly affect the amount and distribution of the stresses in the rail, an instance which occurred in one of the early tests may be cited. A test was being made to compare the results obtained by the strain gauge and the stremmatograph. The stremmatograph record showed almost no stress under the third driver of the Mikado locomotive. Strain gauge read-

SPEED-STRESS DIAGRAMS FOR LOW SPOT IN TRACK.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD.
WITH ATLANTIC LOCOMOTIVE.

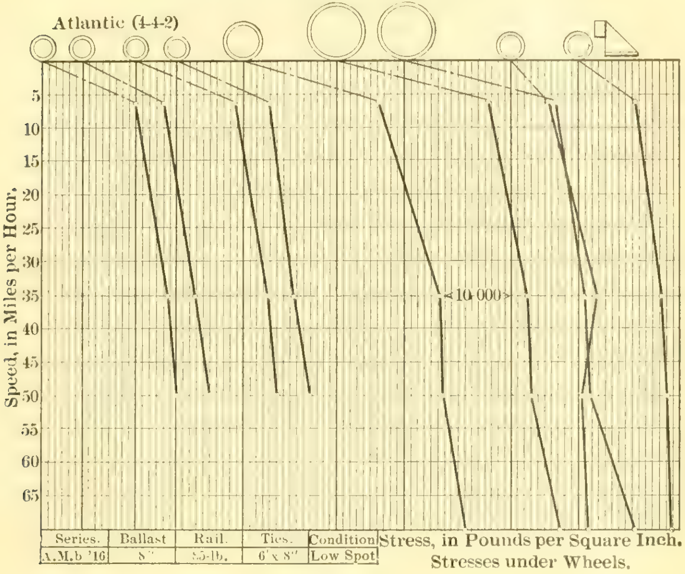


FIG. 134–a.

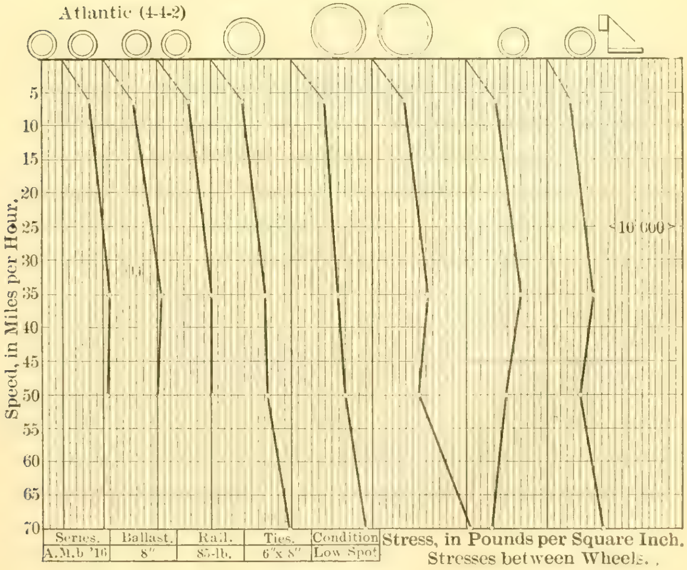


FIG. 134–b.

SPEED-STRESS DIAGRAMS FOR LOW SPOT IN TRACK.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD.
WITH ATLANTIC LOCOMOTIVE.

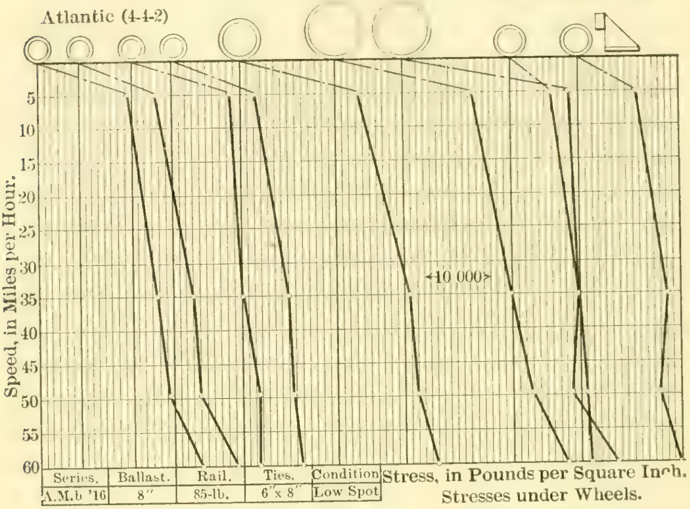


FIG. 135–a.

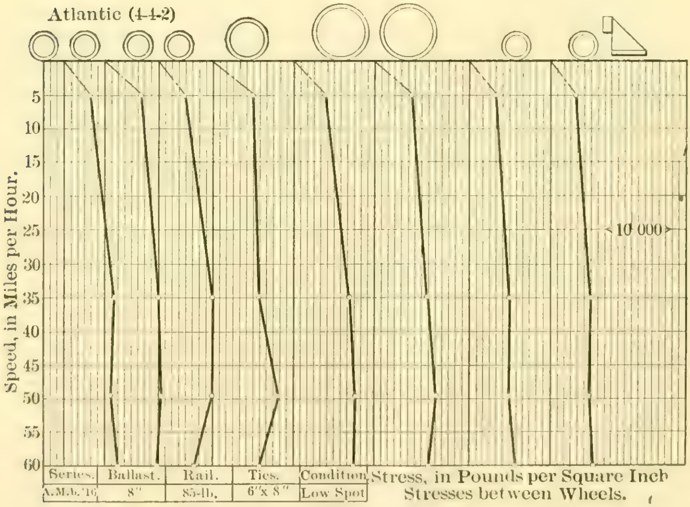


FIG. 135–b.

SPEED-STRESS DIAGRAMS FOR LOW SPOT IN TRACK.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD.
WITH ATLANTIC LOCOMOTIVE.

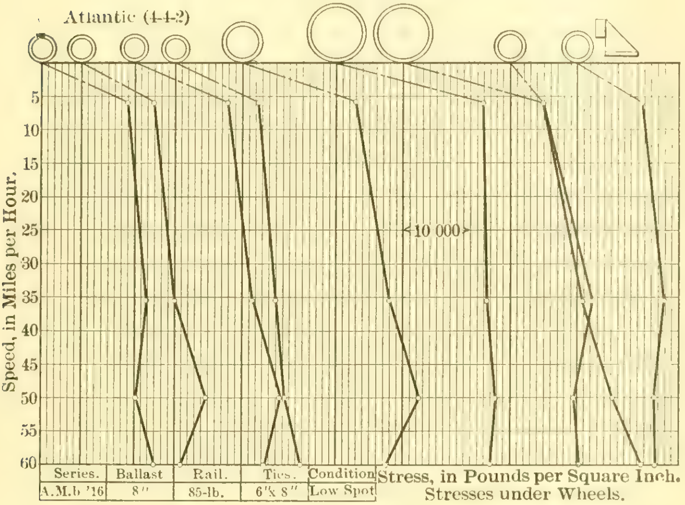


FIG. 136 a.

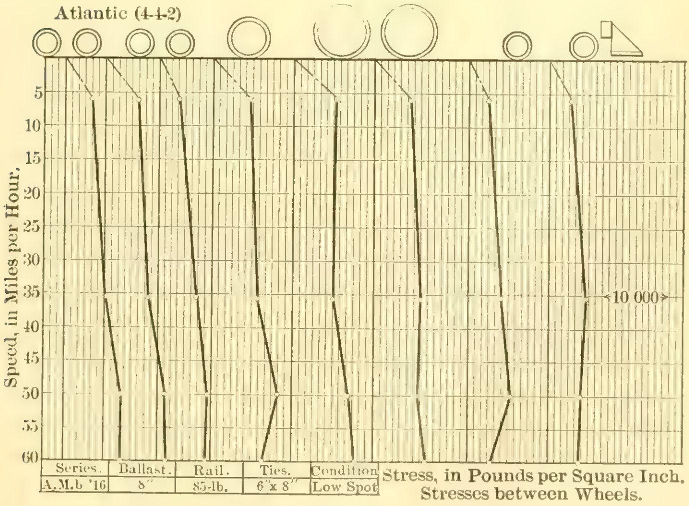
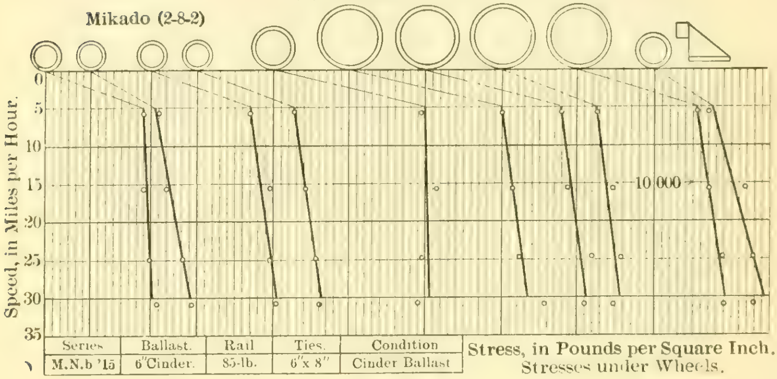


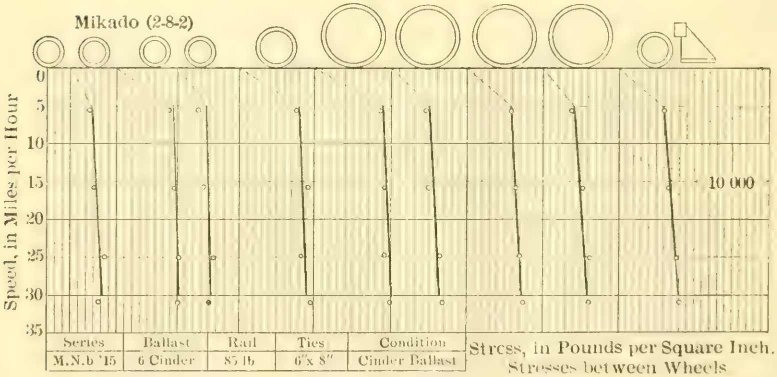
FIG. 136–b.

SPEED-STRESS DIAGRAMS FOR CINDER BALLAST.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.



Series	Ballast.	Rail	Ties.	Condition
M.N.b '15	6″Cinder.	85-lb.	6″x 8″	Cinder Ballast

FIG. 137–a.



Series	Ballast	Rail	Ties	Condition
M.N.b '15	6 Cinder	85 lb	6″x 8″	Cinder Ballast

FIG. 137–b.

ings made with static loading gave the same results. An examination showed that the equalizer for the third driver had been temporarily blocked up by the engineman while out on a run, in order to decrease the load on the driver and thus prevent heating of the bearing, and the blocking had not been removed when the locomotive was returned to the roundhouse. In Fig. 138 are given the stresses under the wheels obtained by strain gauge measurements when the equalizer was blocked up, and also the values obtained with the locomotive in normal condition. It is seen that the stress under the fourth driver was greatly increased, and that those under the second driver and the trailer were somewhat larger than for normal conditions.

53.—Relation of the Stresses on the Two Sides of the Rail.—It may appear natural to think that, since the wheel load is a vertical load, the flexural action in the rail will be such that the fiber stress will be uniform all the way across the base of the rail. Even if the pressure of the wheel is not applied centrally over the head of the rail, the effects of this eccentricity of loading will be to produce vertical flexural stresses in the rail and probably a torsional effect; little lateral horizontal bending of the rail may be expected to result from this source. In planning the tests, lateral bending of the rail was not expected to be an important element. In the earlier test work, therefore, the strain measurements with both the strain gauge and the stremmatograph were made at one edge of the base of the rail only, the outer edge being used because of its greater convenience. The stremmatograph tests showed marked irregularities and seemingly erratic results, which were unexplainable on the ordinary assumption, and steps were taken to find

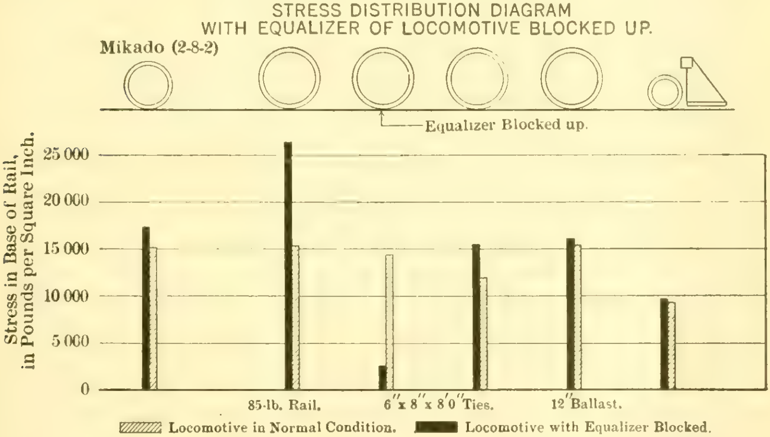


Fig. 138.

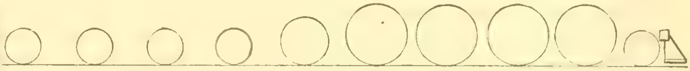
the source of the variations. Tests were made with the position of the stremmatograph reversed on the rail, in order to measure the deformation at the inner edge, and the results were compared with those found with the measurements at the outer edge of the rail, all other conditions as to track, position of locomotive, and speed remaining the same. The average of the stremmatograph measurements at the two edges of the base of rail was found to be fairly uniform and consistent for runs which were comparable, but the stress at one edge was usually different from that at the other, sometimes more than twice as great. Generally speaking, the higher value was found at the outer edge of the rail. The instruments already made were then rebuilt in such way that each stremmatograph measured the deformation both at the inner and outer edges of the base of rail, and this improvement was followed in instruments made thereafter. It may be added that, in static tests with a locomotive, the results of measurements made with a strain gauge showed differences in stresses at the two edges which were quite similar to the results found in the moving-load tests, and that static tests made with the loading device showed little difference in stress on the two sides of the rail.

As another check on the phenomenon, measurements were made at the base of the rail, to see whether the rail showed lateral movement as the wheel moved by. It was observed that there was an outward movement at the base of the rail immediately under the wheel and an inward movement at a point between wheels, the rail thus forming along the length of the locomotive a horizontal curve something like a sinusoid. A similar outward and inward movement occurred in the other rail, and, in the observations referred to, the movements of both rails were outward under a given axle and inward at points between axles; in other words, the gauge of the base of rail was increased at the wheel points and decreased at points between wheels. This movement was small, but it was measurable, ranging from 0.01 in. to 0.03 in., with the 85-lb. rail in the preliminary test referred to. It will be seen, later, that the movement of the rail is not always of the character just described, there being several forms of movement.

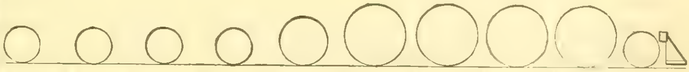
With an outward bending of the rail at a point under a wheel load, the tensile stress at the outer edge of the base of rail is increased over that due to vertical bending, and with an inward bending at a point between wheels, the compressive stress at the outer edge of the base of rail is also increased, the stress at the inner edge of rail being decreased in both cases. In the head of the rail the effect on the stresses is reversed, but, as the head is narrower than the base, the difference in stresses at the two sides of the head of the rail is smaller than that found at the base.

Table 10 gives values of the ratio of the stress at one edge of the base of rail to the mean of the stresses at the two edges. Where the

TABLE 10.—VALUES OF THE RATIO OF THE STRESS AT ONE EDGE OF THE BASE OF RAIL, TO THE MEAN OF THE STRESSES AT THE TWO EDGES. PREPARED TEST SECTIONS OF TRACK.



Speed, in miles per hour.	Instrument No.	85-Lb. Rail			6-In. × 8-In. × 8-Ft. Ties				12-In. Stone Ballast		
5	2	1.12	1.16	1.10	1.15	1.09	1.10	1.18	1.16	1.13	1.05
	3	1.13	1.07	1.05	1.11	1.05	1.00	1.02	— 1.04	1.03	1.06
	4	— 1.03	1.04	1.03	1.11	1.04	1.09	1.08	1.08	1.00	1.01
	7	— 1.18	1.10	1.09	1.15	1.02	1.07	1.10	1.02	1.09	— 1.07
15	2	1.11	1.06	1.05	1.13	1.10	1.08	1.15	1.12	1.08	1.04
	3	1.02	— 1.02	— 1.01	1.07	— 1.01	1.02	1.07	1.04	— 1.01	— 1.05
	4	1.12	1.09	1.07	1.13	1.04	1.09	1.11	1.02	1.07	1.01
	7	1.07	1.07	1.04	1.17	1.05	1.10	1.11	1.02	1.07	- 1.14
25	2	1.13	1.11	1.07	1.19	1.12	1.02	1.10	1.08	1.11	— 1.07
	3	1.05	1.03	1.05	1.00	— 1.08	— 1.04	1.10	— 1.08	1.01	— 1.09
	4	1.12	1.10	1.10	1.13	1.07	1.02	1.07	1.09	1.03	1.08
	7	1.09	1.01	1.17	1.10	1.00	1.05	1.05	1.07	1.05	- 1.07
35	2	1.01	1.05	1.00	1.00	1.04	1.06	1.04	1.05	1.18	— 1.15
	3	1.03	— 1.02	— 1.01	1.03	1.00	— 1.06	— 1.05	1.02	1.01	— 1.06
	4	1.10	— 1.11	1.07	1.04	1.01	— 1.02	1.05	— 1.01	1.00	— 1.02
	7	1.05	1.04	1.09	1.05	1.07	— 1.02	1.11	1.06	1.02	1.00



Speed, in miles per hour.	Instrument No.	125-Lb. Rail			6-In. × 8-In. × 8-Ft. Ties				24-In. Stone Ballast		
5	8	1.15	1.11	1.18	1.09	1.14	1.12	1.11	1.05	1.20	1.14
	9	1.10	1.10	1.02	1.14	1.13	1.11	1.20	1.17	1.11	1.09
	11	1.07	1.09	1.05	1.15	1.14	1.14	1.26	1.23	1.13	1.13
	12	1.05	1.05	1.09	1.21	1.20	1.22	1.25	1.22	1.25	1.12
15	8	1.08	1.05	1.10	1.04	1.07	1.05	1.06	1.03	1.09	— 1.01
	9	1.11	1.09	1.01	1.13	1.10	1.12	1.26	1.15	1.15	1.13
	11	1.07	1.05	1.02	1.12	1.15	1.19	1.30	1.24	1.19	1.20
	12	1.17	1.11	1.24	1.22	1.24	1.16	1.37	1.32	1.31	1.15
25	8	1.07	1.02	1.02	— 1.02	1.02	1.07	— 1.02	1.06	— 1.03	— 1.01
	9	1.13	1.12	1.04	1.18	1.10	1.09	1.26	1.25	1.19	1.13
	11	1.12	1.12	1.06	1.16	1.10	1.11	1.23	1.19	1.24	1.13
	12	1.25	1.22	1.13	1.24	1.11	1.19	1.17	1.20	1.23	1.12
35	8	— 1.03	— 1.06	1.06	— 1.03	— 1.01	— 1.07	— 1.07	1.00	— 1.10	1.03
	9	1.09	1.06	1.03	1.09	1.07	1.04	1.25	1.15	1.09	1.04
	11	1.12	1.12	1.06	1.15	1.08	1.10	1.15	1.07	1.12	1.11
	12	1.10	1.08	1.14	1.20	1.10	1.22	1.11	1.22	1.17	1.28

minus sign is given, the stress at the inner edge is the greater; otherwise, that at the outer edge is the greater. The table is a sample of the data obtained (the complete data being very voluminous), and is probably representative of the observations. The values given are those found by individual instruments; averages of several instruments would mask the effect of variations in track and of variations in movement of locomotive. In looking over the table, it should be borne in mind that the runs were made in such a way that the counterweight of the front driver, on the side of the track on which there were three instruments, was at its lowest point as it passed the middle instrument, and that the succeeding wheels made their records at a later time, and, therefore, the measurement of stresses for the several wheels was not made simultaneously. Naturally, the values cover quite a range. There are many ratios as high as 1.30, and a number as great as 1.50 (which means that the stress at one edge of the base is 1.86 and three times as great, respectively, as the stress at the other edge). The few ratios higher than 1.75 doubtless may not be fully reliable.

The ratios at points midway between wheels (not given in the table) run to even higher values, and are more discordant, as might be expected from the fact that the magnitude of the stress is less than that at points under the wheels. The difference between the numerical values of the stresses at the two edges, as may be expected, is in general less at the point between wheels than at points under the wheels.

The phenomenon of difference in stress at the two sides of the rail is found at all speeds. The magnitude of the stress at either edge of the base of rail varies with the speed, generally increasing with increase of speed, though sometimes the stress at one edge decreases with the speed. In general, the ratio of the stresses at the two edges of the base of rail is not noticeably different at high than at low speeds. In fact, the changes in stress with speed are quite consistent at each edge, as is shown in Fig. 139.

It appears that one of the elements which affect the differences in stresses developed at the two edges of the base of rail is the condition of the track. Higher ratios are found more frequently in track not recently tamped. An excellent example of the effect of the condition of track is seen in the observations at the two locations having a tie in the partly decayed condition previously referred to. The position of the instruments with reference to the poor tie is shown on Fig. 131. The ratio of the stress at edge of rail to the mean of the stresses at the two edges is given in Table 11. Each value given for a single instrument is the average of the results of several runs at a given speed; individual runs give higher ratios. In the test at *I*, Fig. 26, for Instrument No. 2, which was next to the decayed tie, the average of the ratios under the drivers and trailer for all speeds is 1.35 (about 80 readings in all). The average of the highest values found at each speed for all the drivers and trailer is 1.46 (about 16 readings included in getting this average). Stated in the other way, this means that the stress at the outer edge of the base of rail is about 2.1 times the stress at the inner edge when the ratio is 1.35, and 2.7 times when the ratio is 1.46. For Instrument No. 3 (at the tie space ahead of No. 2), the average ratio at all speeds is 1.26, the highest being 1.36. For Instrument No. 7, which was on the other rail and opposite Instrument No. 3 (this end of the decayed tie being sound), the variation in stresses is the same as at No. 3 (that is, the rail bends outward); the average of the ratios at all speeds is 1.10, with a maximum of 1.14. For Instrument No. 4, ahead of No. 3 and on the other side of the decayed tie, the ratio is 1.16 and runs sometimes positive and sometimes negative. For this instrument, the ratios given by the records at the time the instrument was midway between wheels are high, the average for all the wheels and all the runs being 1.48, with maximum values of 1.67.

SPEED-STRESS DIAGRAM FOR EACH EDGE OF BASE OF RAIL.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE.

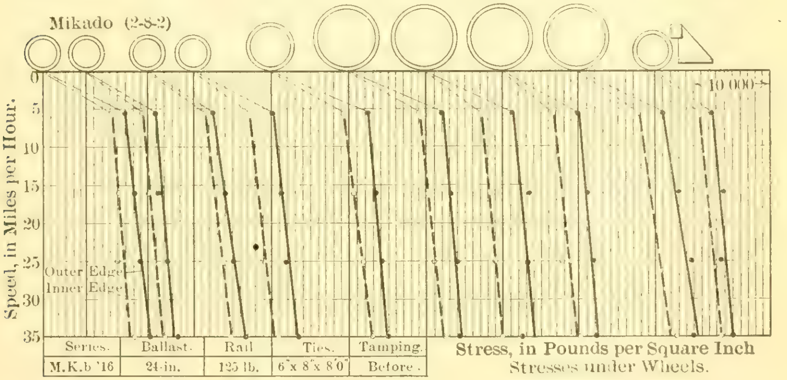


FIG. 139.

In the case of the other test location at a partly decayed tie (*L*, Fig. 26), the instruments were placed on one rail only. The values in Table 11 show highest values for Instrument No. 7, although No. 4 gives nearly as high an average. One driver gives an average ratio at all speeds of 1.43, with a maximum of 1.50 at one speed.

High ratios of the stress at edge of base of rail to the mean of the stresses at the two edges were found in the case of track ballasted with cinders. This track (*N*, Fig. 26) was not in as good surface and alignment as that of the main line. Table 12 gives the ratios under the drivers and trailer at the several speeds. It is seen that ratios as high as 1.35 were not infrequent. In Fig. 140 the stresses at the two edges of the rail, found by averaging the results from the four instruments, are shown for the four speeds used. It is seen that for each wheel the stress at one edge of the base of rail is in general consistently larger than at the other. The averages of all the instruments at 30 miles per hour give stresses of 31 000 lb., and the records of individual instruments were as high as 35 000 lb. (the latter being, of course, the average of several runs).

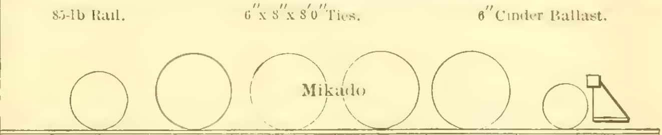
TABLE 11.—VALUES OF THE RATIO OF THE STRESS AT ONE EDGE OF THE BASE OF RAIL TO THE MEAN OF THE STRESSES AT THE TWO EDGES. TIE IN PARTLY DECAYED CONDITION.

Speed, in miles per hour.	Instrument No.	85-LB. RAIL 6 IN. × 8 IN. × 8-FT. TIES 6-IN. STONE BALLAST Location I									
5	2	1·31	1.38	1.34	1.58	1.24	1.34	1.40	1.52	1.45	1.23
	3	1·19	1.07	1.36	1.49	1.19	1.22	1.36	1.23	1.23	1.13
	4	1.02	1.09	1.06	1.03	— 1.01	1.07	1.10	1.07	1.14	— 1.08
	7	1.14	1.19	1.11	1.30	1.04	1.13	1.12	1.13	1.17	1.17
15	2	1.24	1.28	1.30	1.39	1.23	1.26	1.34	1.34	1.53	1.00
	4	1.01	— 1.14	— 1.12	1.14	— 1.20	1.26	1.18	1.00	1.14	— 1.19
	7	1.02	1.13	1.09	1.37	1.08	1.10	1.13	1.14	1.11	1.33
25	2	1.26	1.31	1.29	1.36	1.26	1.30	1.35	1.35	1.32	1.25
	3	1.14	1.19	1.14	1.33	1.16	1.27	1.36	1.36	1.18	1.14
	4	— 1.37	— 1.43	— 1.22	— 1.04	— 1.45	— 1.16	— 1.03	— 1.61	— 1.10	— 1.45
	7	1.00	1.12	1.06	1.34	1.13	1.03	1.09	1.05	1.15	1.35
35	2	1.26	1.29	1.18	1.41	1.26	1.28	1.29	1.39	1.34	1.39
	4	— 1.14	— 1.51	1.19	— 1.08	1.15	1.28	— 1.24	— 1.47	1.06	— 1.26
	7	1.02	1.22	1.09	1.16	1.11	— 1.10	— 1.01	1.04	— 1.09	1.20
		85-LB. RAIL 6 IN. × 8 IN. × 8-FT. TIES 15-IN. STONE BALLAST Location L									
5	7	— 1.03	1.05	— 1.01	1.25	1.11	— 1.14	1.07	1.00	1.29	1.11
	4	1.28	1.33	1.34	1.37	1.26	1.23	1.35	1.32	1.18	1.17
	2	1.01	1.37	1.11	1.29	1.13	1.16	1.22	1.28	1.27	1.05
15	7	1.06	1.07	1.13	1.38	1.11	1.01	1.11	1.08	1.30	1.11
	4	1.15	1.09	1.09	1.31	1.20	1.22	1.37	1.25	1.31	1.19
	2	1.20	1.11	1 21	1.39	1.21	1.25	1.41	1.23	1.07	1.01
25	7	1.12	1.11	1.11	1.40	1.07	1.07	1.24	1.10	1.27	1.14
	4	1.19	1.09	1.06	1.42	1.11	1.25	1.40	1.25	1.41	1.23
	2	1.27	1.24	1.28	1.56	1.12	1.33	1.47	1.37	1.37	1.24
25	7	1.14	— 1.06	1.03	1.22	1.06	1.06	1.19	1.11	1.14	1.03
	2	1.32	1.28	1.44	1.48	1.15	1.27	1.50	1.28	1.31	1.30

Some high values of ratios found on the prepared test track when in good condition are given in Table 13 which gives the results of a single run with a Mikado locomotive at a speed of 35 miles per hour.

It is seen that at Instrument No. 4 all wheels except one give high ratios, the highest being 1.75 (the stress at the outer edge in this case being 35 000 and that at the inner edge 5 000 lb. per sq. in.). At Instrument No. 2, the stresses at the inner edge are usually higher than those at the outer.

TABLE 12.—VALUES OF THE RATIO OF THE STRESS AT ONE EDGE OF THE BASE OF RAIL TO THE MEAN OF THE STRESSES AT THE TWO EDGES. TRACK WITH CINDER BALLAST.



Speed in Miles per Hour.								
5		1.24	1.22	1.31	1.26	1.14	1.09	
15		1.22	1.17	1.35	1.30	1.25	1.22	
25		1.13	1.24	1.45	1.32	1.27	1.05	
30		1.17	1.28	1.42	1.33	1.31	1.20	

A study of the data, including a large amount not here reported, shows that the stress at the outer edge of base of rail is almost always larger than that at the inner edge, and also that, generally, both rails bend outward under the wheel loads. Sometimes one rail bends inward as the other bends outward, indicating a swing of the load. Generally, the bending is inward at a point between wheels, but sometimes it is in the reverse direction. To what extent the coning of the wheels contributes to the outward bending of the rail and what other factors enter into the action will not be discussed in this report. In relation to this matter, it should be noted that, for the tests with the loading jacks, very little difference was found in the stresses at the two sides of the rail.

It seems evident, from a study of all the data, that stresses at the edge of base of rail 30% greater than those due to vertical load may be expected in what would be considered good track, and that occasional values considerably higher than 30% are probable. With track in poor condition, the lateral bending of the rail is even greater. This means that the lateral strength of the rail is an important element in track resistance. For the various rail sections used, the section modulus, $\frac{I}{c}$, with reference to a vertical axis, averages about $\frac{23}{100}$ of that for a horizontal axis. The lateral bending moment, then, is much less than the vertical, but its effect in increasing the fiber stress is such that it needs consideration in the determination of stresses in rail.

54.—Variation in Measured Stresses, and the Relation between Average and Maximum Stress.—The stress developed in the rail under moving loads applied through locomotive and car wheels may not be expected to have the same magnitude for different applications of load at the same place, or for different places having nominally the same conditions. What variations from the average stresses already reported may be expected to occur and what maximum stresses may be expected are matters of importance. To arrive at a judgment on these questions will require a study of the variation in the observed values and of the probable errors of observation. Having determined the limiting error of observation which is probable and also the variation in the observed values which may be expected, a value of the probable limiting variation in the actual stress developed in the rail may be approximated, which will assist in judging what maximum stress may be expected to occur.

SPEED-STRESS DIAGRAM FOR EACH EDGE OF BASE OF RAIL.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE.
TRACK WITH CINDER BALLAST.

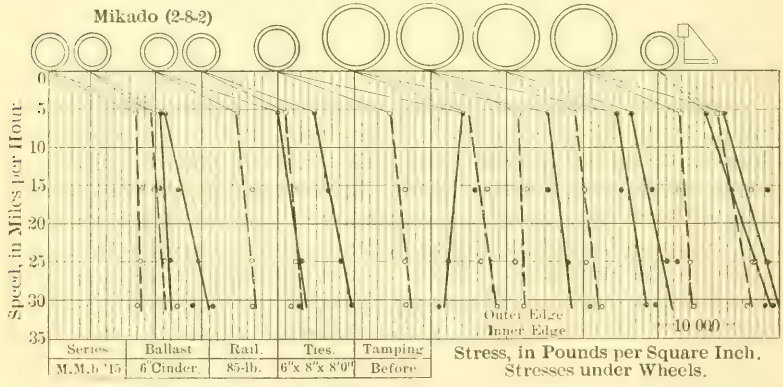
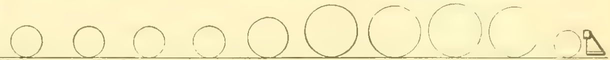


FIG. 140.

With the exception of the results given in the discussion on the "Relation of the Stresses on the Two Sides of the Rail", the stresses recorded in the tables and on the diagrams represent the average of a large number of observations. For a given speed and a given wheel, the results usually include the results of four instruments (each having a record for the inside edge of the rail and for the outside edge) for four runs at each of three adjoining locations on the track, say, counting out imperfect records, 90 observations in all; the average of the 90 observations is recorded as the value for the given wheel at the given speed. In the case of the tests on track at unsound ties and at low spots, the values given are the averages for one instrument, say 8 observations in all for each wheel at a given speed. For the comparison of stresses on the two sides of the rail, the values given are the average of the records on a stremmatograph disk at one side of the rail at three locations, say, 12 observations at each speed and 48 observations for all speeds. It is evident that the individual observations will vary from the average result reported. Part of this variation will be due to errors in observation, and part will represent actual variation in the stresses in the rail.

TABLE 13.—VALUES OF THE RATIO OF THE STRESS AT ONE EDGE OF THE BASE OF RAIL TO THE MEAN OF THE STRESSES AT THE TWO EDGES FOR A SINGLE RUN ON A PREPARED TEST SECTION OF TRACK.

Speed, in Miles per Hour.	Instrument No.	85 lb. Rail. 6″ x 8″ x 8′ 0″ Ties. 6″ Stone Ballast.									
											
35	2	−1.06	−1.15	−1.23	−1.20	−1.25	−1.01	−1.16	−1.03	−1.13	−1.14
	3	−1.20	−1.13	1.07	1.00	1.17	1.15	−1.05	1.23	1.12	−1.05
	4	1.20	1.06	1.49	1.23	1.48	1.73	1.11	1.00	1.31	1.00

Variations in the actual stress in the rail under nominally the same conditions may be due to differences in the way the locomotive wheels and car wheels are applied to the track in runs made at different times, as, for illustration, that produced by nosing or rolling, or by variations in the action of equalizers and springs; and they may be due to differences in the way the rail-support (ties, ballast, etc.) acts under changes in method of application of load, or to actual difference in the resisting action of the track support at two locations having seemingly the same conditions.

The sources of observational errors are: (1) inherent characteristics in the design of the instruments, such as that in the stremmatograph used in part of the 1915 tests; (2) looseness or play in bearings of record disk, or somewhere in the clamps; (3) accidental conditions of operation, such as result from variable jolts or blows on the track, and from variable inertia effects in the instrument; and (4) errors in reading the record.

The first-mentioned source may give errors which are proportional to the stress, or nearly so. This sort of instrumental error was found in the stremmatograph used in part of the 1915 tests. It is believed that the design of the later instruments avoided errors of this kind which were of any magnitude. The second source of instrumental error gives variable accidental conditions in the use of the instrument. In the stremmatograph used, the presence of this condition, when sufficient in amount, could be detected by an examination of the record in the field, and the instrument could be adjusted at once. Usually, a variation in the action of the instrument, equivalent to a stress of 600 lb. per sq. in., could be detected. When it was seen that the variation amounted to more than 1 000 lb. per sq. in., the observation in question was discarded. For variations between these two general limits, the observation was used, and an allowance was made, and the error from this source may not be expected to reach more than 600 lb. per sq. in. for an individual observation. The variations from the third source, accidental conditions, frequently could be told from the characteristics of the record. When such a variation was marked, the observation was discarded. Notwithstanding this, there must exist in the results obtained from the records many variations which are due to accidental instrumental errors. Of the fourth source, that of reading the record, it has already been stated that in the early part of the work the average variation of the readings of the records made by either of two observers from the average reading of the two was 400 lb. per sq. in., and that, with later experience, it is believed that there are very few readings in error more than 700 lb. per sq. in. It may be noted that, except for the first source, the errors are as likely to be positive as negative, and that, except for the accidental instrumental errors, they are largely independent of the magnitude of the stress; that is, they are not greater for large than for small stresses.

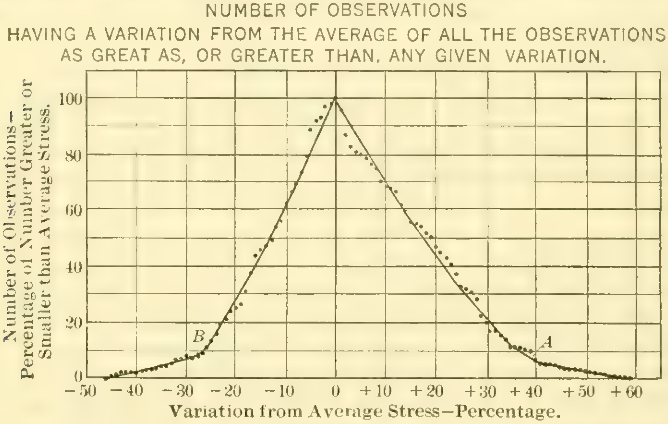


FIG. 141.

For the study of the variations, a number of sets of test results were chosen at random. These included tests made with 85-lb., 100-lb., and 125-lb. rail at the several speeds used, for each edge of base of rail, and for the mean of the two edges. Diagrams were plotted for each set, in order to show the relation between the magnitude of the variation from the mean and the number of observations. Fig. 141 shows one of these. The horizontal scale gives the variation from the average value of all the observations as a percentage of the average stress. The vertical scale gives the number of observations having a variation from the average value as great as, or greater than, the variation in question. At two points on these diagrams, such as *A* and *B*, a rather marked change in slope or break in the curve was found. Although the several diagrams differed somewhat in the variation indicated at these characteristic points, the location of the points did not vary much from a little less than 10% of the number of observations, and the average magnitude of the variation at these points was ± 38% of the average stress. Outside of these points, the number of observations corresponding to the variations became smaller, but there were always several values at or beyond ± 50% grouped in such a way as to seem well substantiated. Beyond these the observations were few and very irregularly placed. It may be stated, then, that, in the sets studied, 10% of the observations gave variations from the average stress of as much as ± 38% of the average stress, and that always there were seemingly well substantiated variations as great as ± 50 per cent.

In the several sets of results studied, the mean variation of the individual observations from the average stress did not differ much; it averaged ± 22 per cent. Similarly, the probable error of a single observation, calculated by the theory of errors, was nearly the same in all the sets, averaging ± 18 per cent. The diagrams, such as that in Fig. 141, are very similar in form to the curve of the probability integral, as they may be expected to be, both because the errors of observation will follow the laws of chance and because the causes which produce variable stresses in the rail may also be expected to follow the laws of chance in the frequency of their application. The different sets of results which were studied had common characteristics; the variations at the line of 10% of number of observations (± 38%), the values of the mean variation from average stress, and the probable error differed little in the several sets. They were about the same at all speeds, for all wheels, and for both edges of the rail. This is all characteristic of accidental differences.

A consideration of the source and probable amount of the observational errors leads to the view that in 90% of the observations the error of a single observation will be less than 15% of the observed stress, and, of course, generally much less than this. This estimate takes into account both the observational errors that are independent of the magnitude of the stress and those that may be proportional to it; this limit of error may be somewhat too small for low stresses, such as 5 000 to 10 000 lb. per sq. in., and somewhat too large for high stresses

If then it be assumed that the error of observation for the observed stress at which there are 10% of the observations giving greater variation (*B*, in Fig. 141) is ± 15%, and the variation of this observed stress from the average is taken as ± 38%, it will be seen that the actual value of the stress in the rail which was observed as 1 + 38% may be as small as $\frac{1.38}{1.15}$ × average stress, or 20% more than the average; and, of course, it might be as large as $\frac{1.38}{0.85}$ × average stress, or 62% more than the average. Similarly, for an observed stress 50% greater than the average, assuming that the limit of error of observation is ± 20%, the actual stress in the rail may be as small as 25% more than the average. It may be asserted, then, that, for nominally the same conditions of track and of load values of the stress in the rail, 20% greater than the averages reported in the diagrams and tables, or even 25% greater, may be expected not infrequently, and, of course, by the theory of chance, the probabilities are that these values may be exceeded considerably. In any effort to determine the maximum stress which may be developed in a rail, this excess of the individual values of the stress over the value obtained by averaging results must be taken into account.

55.—Method of Estimating Maximum Flexural Stress in Rail for Given Conditions of Track and Loading.—What maximum flexural stress may be developed in a rail under given conditions of track and loading is a matter of considerable interest. In making an estimate of the maximum stress, it will be well to start with the average stress which may be expected at low speeds for the best conditions of track, and introduce a series of factors covering the several sources of increase or variation from average stress at low speeds. Such an equation for flexural stress in the rail is

$$f = f_0 \, (1 + a) \, (1 + b) \, (1 + c) \, (1 + d)$$

$$= \begin{pmatrix}\text{average stress}\\ \text{at 5 miles per}\\ \text{hour.}\end{pmatrix} \begin{pmatrix}\text{speed}\\ \text{factor.}\\ \end{pmatrix} \begin{pmatrix}\text{lateral}\\ \text{bending}\\ \text{factor.}\end{pmatrix} \begin{pmatrix}\text{condition}\\ \text{of track}\\ \text{factor.}\end{pmatrix} \begin{pmatrix}\text{varia-}\\ \text{bility}\\ \text{factor.}\end{pmatrix}$$

These factors have already been discussed to some extent. The average stress at 5 miles per hour would depend on the locomotive loading and the nature of the track (rail, ties, ballast, etc.). For the "condition of track factor" the presence of low spots, defective ties, and other imperfect conditions must be considered, and, even on fairly well-kept track, this factor will need consideration. The Committee plans to discuss in another report the magnitude of maximum stress for various conditions of track and loading. It is evident that the maximum stress which may be developed in the rail under usual conditions of track and traffic may be much higher than the average stresses found for best track at low speeds, and that speed factor, lateral bending factor, condition of track factor, and variability factor should be recognized in making an estimate of the maximum stress to which the rail will be subjected.

56.—The Test Work on Ties, Ballast, and Roadway.—Considerable progress has been made in the experimental study of the action of ties, ballast, and roadway. Tests on track have included the measurements of the depression produced under load at various points below the tie and across and along the track and roadway. The measurement of pressure in ballast with the pressure-capsule has given interesting data. Information has also been obtained with the recording pressure-capsules. Measurement of the flexure of the tie has been made. Before completing tests on this part of the problem, it was deemed wise to await the results of laboratory tests, in order to determine the principles governing the distribution of pressure through ballast material, as this information would guide the extension of the tests and be useful in interpreting the data obtained.

The laboratory tests on transmission of pressure through ballast material have advantages over tests made in the field, in that the conditions may be controlled more definitely and exactly and the tests repeated under identical conditions. In the experiments, several ties are spaced as usual over a given depth of ballast, and loads are applied on the rails. By having a number of pressure-capsules inserted in the ballast at the different depths and positions at which the measurement of pressure is desired and then changing tie spacing and other variables, information bearing on the problem is obtained. Tests have been made with broken stone, gravel, and sand as ballast material. Advantage has been taken of information and experience gained in tests on the transmission of pressure through granular material previously carried on in the laboratory. It seems evident, from the experimental data obtained, that quite definite laws govern the transmission and distribution of pressure through ballast materials, and that these principles have a very direct bearing on the effectiveness of different depths of ballast and different conditions of ties and tie spacing. The results of the investigation on ties, ballast, and roadway will be presented in another report.

Respectfully submitted,

The Committee to Report on Stresses in Railroad Track

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NOVEMBER 3D, 1917.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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OBSTRUCTION OF BRIDGE PIERS TO THE FLOW OF WATER

Discussion.*

By Robert E. Horton, M. Am. Soc. C. E.

Robert E. Horton,† M. Am. Soc. C. E. (by letter).‡—Hydraulic books are replete with experimental data applicable to certain categorical formulas under so-called standard conditions. Problems encountered in practice, probably depart from the standard laid down in textbooks rather more often than they conform to them. The author presents experimental data relative to a matter which falls outside the limits of the usual textbook discussion, in that the flow of water between the piers of a bridge does not conform either to the conditions of the standard weir, so-called, or the standard orifice. It is not to be presumed that reasonably accurate results, sufficiently good for practical purposes, in most cases, may not be obtained under many conditions which would be considered "irregular" from a pedantic standpoint. Textbooks have cautioned engineers too strongly against the extension of results beyond the limits of experiments. Such precaution is undoubtedly proper and necessary for students, but the one point wherein good judgment and ripe experience may be of great value in hydraulic practice is that it enables the experienced and competent engineer to get reasonably good results in many cases from imperfect data or under conditions differing somewhat from those for which experimental data are available. Concededly, every practicing engineer Mr. Horton.

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* Discussion of the paper by Floyd A. Nagler, Jun. Am. Soc. C. E., continued from November, 1917, *Proceedings*.

† Albany, N. Y.

‡ Received by the Secretary, December 12th, 1917.

Mr. Horton. would have preferred the experiments recounted in the paper to have been made on full-sized models. However, the results as they stand are a welcome contribution to the experimental data of hydraulics.

Intelligent discussion of the details of these experiments would be greatly facilitated if the complete results were represented in tabular form. The experiments bear the mark of careful and intelligent work, and it is the writer's view that all such experiments are proper subject matter for presentation in detail in the *Transactions* of the Society. Certainly, to the present generation of engineers, the value of experiments, such as those of Fteley and Stearns and Bazin, is greatly enhanced by virtue of the fact that the original experimental data are available in printed form where they may be compared with more recent experiments.

It is to be hoped that the author's original experiments may be presented in full, in connection with the closure of this paper; and that, in the future, when similar papers are published, wherein intelligent discussion and the requirements of future investigations demand it, the author may be permitted to publish such details.

Just how far these experiments on models of bridge piers can be applied to full-sized piers, under conditions arising in practice, is a difficult problem, especially in the absence of the original experimental data. The fundamental condition of success in an attempt to apply hydraulic data, especially where the application involves an extension beyond the limits of the experiments, is that the results should be used intelligently. Intelligent use generally involves a critical study of the effect of the changed conditions. At present, it appears to be impossible to go beyond the statement that, in the case at hand, if the ratio of the obstructed to the total cross-section is the same as in the experiments and the velocity up stream from the bridge pier is the same, then the eddy loss or contraction, especially at the head of the bridge pier, should follow laws and be determinable in amount, approximately, at least, from experiments on model piers. Losses due to skin friction obviously would not be the same in a large pier as in a small model. Possibly an allowance for this difference could be made by the application of the extensive data available as to skin friction losses from experiments in naval hydrodynamics.

The author has attempted to correlate his results with the formula for flow through orifices. This procedure has the value of throwing some light on the true nature of the flow between bridge piers and the nature of the friction losses. However, for practical purposes of calculation, in cases where the phenomena lie close to the limits of applicability of existing formulas, it is often found better to express the result by wholly empirical formulas. Conventionally, the flow of water is divided into: flow in channels, flow through weirs, and flow

Mr. Horton.

through orifices. It should be realized that there are no hard and fast lines which may be drawn between these categories. In practice, problems arise where the flow partakes of the nature of two and sometimes three of these conditions. The flow past bridge piers is an example of the latter condition.

As the population in a region increases, commercial and industrial developments along streams also increase rapidly; and the obstruction of stream channels by bridge piers becomes of greater importance as development proceeds. It often happens, owing to physiographic conditions, that the natural highway of commerce crosses a given stream in a position requiring several bridges near one another. In such cases, the head losses due to bridge piers often require careful consideration, not only because of the back-water which may be produced by improper construction, in flood seasons, and under ordinary flow conditions; but also because of the danger of the formation of jams of logs, débris, or ice, especially where there are several bridges with numerous piers not in alignment. In a recent case which came to the writer's attention, two bridges had been constructed across the outlet of a large lake. The piers were close together, and in such a position that those down stream obstructed the waterway left between those of the up-stream bridge. To the casual observer the head loss appeared to be small. Both measurement and calculation, however, indicated that it was of considerable moment, especially in view of the fact that the back-water which it caused affected the entire perimeter of the lake above, which was about 60 miles in length.

The author states that Gauge No. 3 measures the head up stream from the weir crest at a distance proportional to the ratio of the height of the weir to the height of the experimental weir used by Bazin. It appears to the writer that, inasmuch as the author's weir was lower than that of Bazin, the velocity of approach and surface curvature would be greater for a given depth on the weir, and the gauge should have been placed at the same distance up stream, or else at a greater distance than that of Bazin's.

In Fig. 10, showing the comparison of the experimental friction loss with that obtained by the application of Kutter's formula, the author should state what value was used for the coefficient of roughness, n.

The writer has had occasion to make a study of the comparative results obtained in computing back-water according to the different formulas mentioned by the author. The problem was as follows: A canal discharging 1 500 cu. ft. per sec. had an irregular cross-section with a mean width of 88 ft. and a mean depth of 8 ft. A pier 11 ft. wide was to be erected in the center of the section. It was desired to find the height of back-water or h. The following results were

Mr. Horton. obtained, using the coefficients recommended by the authors of the respective formulas:

Debauve formula	Coefficient $= 0.96$	$h = 0.107$
Weisbach "	" $= 0.95$	$h = 0.076$
Neville's "	" $= 0.80$	$h = 0.160$
Trautwine's table	....	$h = 0.102$
Molesworth's table	....	$h = 0.110$

The tables of Molesworth and Trautwine are based on a formula similar to that quoted by the author on page 830* and attributed to D'Aubuisson. They modify the formula, however, to take into consideration the value of the slope of the stream bed itself. The formula thus assumes this form:

$$h = \left(\frac{v^2}{k^2\, 2\, g} + s\right) \left\{ \left(\frac{A}{a}\right)^2 - 1 \right\}$$

Louis D'A. Jackson† also gives a table for computing the value of h, using this same formula, but considering s as having a value of zero.

The Neville formula‡ is a submerged-weir formula similar to that of Weisbach.

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* *Proceedings*, Am. Soc. C. E., May, 1917.

† "Hydraulic Manual", Tables, p. 111.

‡ "Hydraulic Tables, Coefficients and Formulas," p. 142.

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PAPERS AND DISCUSSIONS

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DETENTION RESERVOIRS WITH SPILLWAY OUTLETS AS AN AGENCY IN FLOOD CONTROL

Discussion.*

By William M. Hall, M. Am. Soc. C. E.

William M. Hall,† M. Am. Soc. C. E. (by letter).‡—As the late Gen. Chittenden, for a decade or more, had been one of the ablest writers on floods and flood control, in the Society, as well as in the Corps of Engineers, U. S. A., the writer feels that it is especially fortunate that, before "going over the last divide", he gave his opinions on the possibility of using reservoirs for flood control and of combining the detention reservoir and the storage reservoir for power or other purposes, thereby clearing up some misapprehensions regarding his views thereon, which might have been drawn from his former papers. Mr. Hall.

The writer fully concurs in the opinion that, on large streams, such as the Lower Mississippi, flood control by reservoirs is impracticable, but that, on small streams, such as the tributaries of the Ohio above the Cumberland and Tennessee, it is practicable thus to control or regulate flood stages. However, in some cases, other methods may be more economical, and, in other cases, there may be no favorable sites for reservoirs.

Notwithstanding the conflict between reservoir space for flood control, and reservoir space for power or other purposes of utility, described by the author, the writer believes that, in some cases, the two may be combined advantageously and economically if it becomes to the interest of an owner of a reservoir to use it in that way;

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* Discussion of the paper by the late H. M. Chittenden, M. Am. Soc. C. E., continued from December, 1917, *Proceedings*.

† Parkersburg, W. Va.

‡ Received by the Secretary, December 24th, 1917.

Mr. Hall. or, such a combination may be made to the advantage of two or more owners working in harmony through a single management.

The writer wishes to suggest a thought in reference to the method of harmonizing the conflicting usage:

As the season of floods, in all the Eastern United States, is principally during the period from December to April; and, as the natural flow during that time will generally produce much greater power than the natural flow during the dry season, a dam or plant could be designed for the production of power exclusively by natural flow during the time of greatest floods, thereby using the upper storage space during that period for flood control and immediately thereafter filling the same storage space and using it during the dry season exclusively for power or other plant purposes. Such an arrangement would not afford perfect protection; but, at comparatively small additional cost to that for power, it could be made to reduce the flood hazard greatly. As an example, consider the flood conditions and records of the Monongahela and Allegheny Rivers, at Pittsburgh, Pa. Table 3, published by the U. S. Weather Bureau, may be used as an illustration. It is observed that, during the period of 110 years covered by this table, there were three floods in May (one of 22 ft., one of 23 ft., and one of 26 ft.), one in June (24 ft.), two in July (one of 22 ft. and one of 23 ft.), one in August (26 ft.), three in September (two of 31 ft. and one of 25 ft.), none in October, and three in November (one of 22 ft., one of 28 ft., and one of 23 ft.), or thirteen floods between April and December for the entire period. It may be concluded, therefore, that had Pittsburgh had the partial protection of a series of power dams, designed with sufficient flood-storage space to hold the crest wave above a 22 to 26-ft. stage, and operated from December 1st to April 31st, it would have had, during the period, only four floods above a 26-ft. stage; or, in other words, floods which would be classed as serious disasters, an average of only one such flood each 27 years.

Although such an arrangement would not have given perfect protection, it would have prevented great property loss and damage from the other twenty-five floods above a 26-ft. stage, which it is observed occurred during that period in the five flood months of December to April.

It is believed that the execution of the project, as designed and proposed by the Flood Commission of Pittsburgh, is stopped by its great cost, and not by lack of public faith in the project *per se*. The writer thinks that a project for a series of power-flood-protection dams with the expense divided between the power companies and the public, or built at public expense and the power leased or sold, might be more easily carried to completion than one for either purpose alone.

It is believed that a study of many localities east of the Mississippi, now suffering every few years from flood disasters, may show them susceptible of similar relief. To all such localities the question of cost is the most serious one, and to many it is prohibitive. The suggested combination should help to overcome this obstacle. Mr. Hall.

TABLE 3.—RECORD OF FLOODS IN THE OHIO RIVER AT PITTSBURGH.

Year.	Day of month.	Stage at Pittsburgh.	Year.	Day of month.	Stage at Pittsburgh.
1806	April 10	33 9	1890	March 23	24 3
1810	November 9	32 0	1890	May 24	22 0
1813	January -	29 0	1891	January 3	23 2
1816	February —	33 0	1891	February 18	31 3
1832	February 10	35 0	1892	January 15	23 0
1840	February 1	26 8	1893	February 8	24 0
1846	March 15	25 0	1893	February 11	22 0
1847	February 2	26 9	1894	May 22	23 2
1847	December 12	24 0	1895	January 8	25 8
1848	December 22	23 0	1896	July 26	23 0
1851	September 20	30 9	1897	February 24	29 5
1852	April 6	25 0	1898	March 24	28 9
1852	April 19	31 9	1899	March 6	22 0
1858	May 27	26 0	1900	November 27	27 7
1859	April 28	22 0	1901	April 7	22 1
1860	April 12	29 7	1901	April 21	27 5
1860	November 4	22 0	1901	December 16	25 8
1861	September 29	31 0	1902	March 1	32 4
1862	January 21	30 0	1903	February 5	24 0
1862	April 22	25 4	1903	March 1	28 9
1865	March 4	24 5	1904	January 23	30 0
1865	March 18	31 4	1904	March 4	26 9
1867	February 15	22 0	1904	March 8	23 2
1867	March 13	23 5	1905	March 22	29 0
1868	March 18	22 0	1905	December 4	23 5
1873	December 14	25 7	1907	January 20	23 3
1874	January 8	22 2	1907	March 15	35 5
1876	September 19	25 0	1907	March 20	22 4
1877	January 17	24 6	1908	February 16	30 7
1878	December 11	24 5	1908	March 20	27 3
1881	February 11	23 2	1909	February 25	22 3
1881	June 10	27 1	1909	May 1	22 2
1883	February 5	24 8	1910	January 19	22 8
1883	February 8	28 0	1910	March 1	22 0
1884	February 6	33 3	1911	January 15	23 8
1885	January 17	23 0	1911	January 31	25 2
1886	April 7	22 8	1912	March 22	28 1
1887	February 12	22 0	1913	January 9	31 3
1887	February 27	22 0	1913	January 12	26 3
1888	July 11	22 0	1913	March 28	30 4
1888	August 22	26 0	1915	February 3	28 4
1889	June 1	24 0	1915	December 19	22 6

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A PHENOMENAL LAND SLIDE—SUPPLEMENT

Discussion.*

By George L. Dillman, M. Am. Soc. C. E.

George L. Dillman,† M. Am. Soc. C. E. (by letter).‡—It may be said, generally, that engineers have few opportunities to examine their works after completion. Mr. Clarke is to be congratulated on his opportunity to supplement the first drainage by the second construction. The Society is to be congratulated on this supplementary paper. Mr. Dillman.

Without doubt, the reservoir slide at Portland has had the most thorough investigation of any slide on earth. It has extended over many years, has included many shafts and wells through the slide, tunnels under and through it, and careful observation of its movement, in amount and direction. A lawsuit for damages developed facts showing that motion had been periodical for many years before it was recognized as a slide. The surface was covered with timber, and was uninhabited, so that the pertinent facts—cracks at the head of the slide into which cattle fell and had to be rescued, the irregular leaning of trees, and the springs at the toe of the slide now occupied by reservoirs—were not connected as symptoms of a single phenomenon.

The writer now believes that the slide described was in motion for years, possibly hundreds of them, prior to the coming of man, certainly prior to the first Government survey across it. He also confesses to carelessness in observation, when the cable railroad, shown on Plate XII, from Jefferson Street to the City Park, was built in 1891. The

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* This discussion (of the paper by D. D. Clarke, M. Am. Soc. C. E., published in September, 1917, *Proceedings*, but not presented at any meeting, is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† San Francisco, Cal.

‡ Received by the Secretary, December 20th, 1917.

Mr. Dillman. banks of the cuts slid, the slot closed, the cast yokes broke, the trees could not be felled by expert woodsmen in the direction desired, and men on the bridge work across what is now No. 4 Reservoir made a path up the gulch to about where No. 3 Dam was afterward built, to a fine permanent spring. There was a small stream down this gulch, following the toe of what is now known as the slide.

Others were just as unobservant, as is shown by the construction of the reservoirs before learning of this general slide. No one can truthfully say "I told you so" prior to the failure of the western slopes of those reservoirs. Such able engineers as the late James D. Schuyler, and Isaac W. Smith, Members, Am. Soc. C. E., and the author, ignored it. The late W. H. Kennedy, M. Am. Soc. C. E., then Chief Engineer of the Oregon Railroad and Navigation Company, stated to the writer, when the damage suit was on, that the excavation of the reservoirs undoubtedly caused the slide. He changed his mind when the evidence was seen to be overwhelming that the slide had periodic motion long prior thereto. Except Mr. Clarke, these engineers have gone, but they were all men of recognized ability.

To some little extent prior to 1891, but to a very great extent since, the writer has been studying slides. They are the most common phenomena of the Pacific Coast. He knows of them from the Straits of Juan de Fuca to Panama, and has information of them in South America. At first, it would seem that slides are of different kinds; they move laterally, they upheave, they sink, and some seem to be dry. Some move fast enough to be called avalanches, some are slow and regular, and are called locally mud glaciers, some move only at long intervals.

When the Canadian Pacific Railway was built, settlement affected irrigation along it; in one place, a very large area started toward the river. That slide was arrested by stopping the irrigation. The Canadian Pacific Railway Company purchased the farms and abandoned them.

The Oregon Railroad and Navigation Company first built its road past the Cascades of the Columbia on a shelf blasted out of solid rock. The road still rests on the same shelf, but instrumental work has shown that it has moved (with its mountain) more than 17 ft. northward. That slide is slow. The depth of the river above shows that the Cascades, originally, were made by a slide. Probably erosion is compensated for by motion, certainly from the south, possibly from the north. The Indian legend of a natural bridge at the Cascades is entirely reasonable, and is supported by collateral facts.

There is a slide at Tillamook, which includes several hundred acres of land and the Tillamook Light. Its motion is small, and might not have been discovered but for the failure of a small bridge across its trace on the surface.

Mr. Dillman

The Cow Creek slide on the Oregon and Cascades Railway, in Oregon, interrupted operations so many times and so seriously as to warrant several miles of new construction of heavy work in order to avoid it. This slide has never been cured, and is probably not worth curing.

A slide in Berkeley, Cal., a few years ago included many houses. It was cured (thus far completely) by the abandonment of a lily and frog pond at its head. Until the writer examined and pointed out this contributing cause, the pond had been maintained by a Professor in the Geological Department of the University of California. Geology has much to say about faults after they occur, but may not go into causes. Incidentally, all faults are caused by slides. Slides may be caused by earthquakes, but most of them are from something else.

All the railroads on the Pacific Coast have to contend with slides. The Northwestern Pacific has the finest collection along its Eel River line. Some are curing themselves, some are being cured by drainage—sub and surface. The Southern Pacific is affected at a few points in the Sacramento Canyon, at Carquinez Straits, in open country just east of Altamont, in the Santa Cruz Mountains, and on the Coast Route to Los Angeles. The Western Pacific is affected in the Feather River Canyon, in the Altamont hills, and the Niles Canyon. The Santa Fé had trouble with its Franklin Tunnel from slide causes. The Ocean Shore is affected in a few places, notably at Mussel Rock.

The San Francisco peninsula has a number of slides. The Sutro Baths were threatened until the slide was cured by drainage and later removal. At Lands End there is a typical slide, moving every year, which is now invading Fort Miley at its head.

One of the most evident slides, and yet one which is entirely unobserved by man, is in the Olympic Mountains. It cut an ancient lake in two, raising one part about 80 ft. to a new outlet. The place from which the material came is still very evident. The slide is now entirely covered by a heavy growth of timber. The lower lake is called Lake Sutherland, with its outlet toward the Elwha. The upper one is Lake Crescent, and its outlet is Crescent Creek.

These instances have been given in order to lead to statements of the cause and cure of slides, or, rather, the contributing cause which can be cured; and it is all very simple. The cause is water, and the cure is drainage.

The Cause is Water.—Water lubricates, and lessens friction. Water accumulates a head, and forces itself into and through otherwise impermeable material, thus extending the lubrication; but the greatest effect of water is from its pressure. It acts like millions of jack-screws, under and back of the slide, to produce motion. The film of water back of and under the slide has only to be thick enough to be continuous in order to transmit the pressure of its whole head in this manner.

Mr. Dillman

We have articles on the pressure of water under dams. A slide is a dam, in all essential features, until motion begins. Then, fortunately, the continuity of the water film is broken. At the instant the continuity is sufficiently broken, motion ceases. Then, if conditions are right, the inflow of water increases the continuity of the film, flows into the cracks, and motion again begins.

A slide is frequently a number of dams, according to different planes of motion, any one of which may move. It matters not how saturated is the mass above the bottom of the slide, the analysis of bottom pressures and effects is not changed thereby. Although slides of some extent offer at first varying evidence, crumpling at the toe, upheaval in places, subsidence at the head, and lateral motion in varying degrees, they can all be traced to one phenomenon by proper analysis. There is frequently a swampy place at the head, sometimes attaining the dignity of a lake. There are usually springs at the toe, frequently also along its trace on the surface. These may develop by erosion into gulches which hide the cracks, the crumpling, and other evidences of motion.

There is no need to enlarge on the cause of slides. Every fact in evidence can be traced directly to water, principally to its pressure.

The Cure is Drainage.—Sometimes, the surface can be drained sufficiently to effect a cure. Surface drainage will always help; but surface drainage is often difficult, especially after motion has developed a cracked wart-like surface, as this tends to hold rainfall and guide it to the surface of motion, or several surfaces of motion.

Sub-drainage, which will kill the water pressure, is infallible. There never has been a slide that could not be cured in this way. There are cases where the expense is not warranted. There are cases where the whole slide can be sluiced away. There are also cases where the motion is so slow, or its effect so small, that the removal of the material as it comes, or not removing it at all, is the best answer. Incidentally, removal is drainage.

Subsidence at the head of the slide tends to the formation of swamps and lakes, which, in turn, supply the water to fill the cracks, to form the pressure, to produce motion, to make more subsidence, and so on in a never-ending cycle. The interruption of this cycle is most certainly accomplished by killing the head of water acting on the surface of motion. Draining the swamps and lakes will help. At Panama one enthusiast proposed concreting the whole surface of the slide to prevent the ingress of water. This might do, if there were not probably some subterranean supply of water, possibly with a great head, that would not keep out. Such construction might be an actual hindrance, instead of a help, and might serve to hold the water and increase, instead of decrease, the head.

In some cases increasing the resistance to motion has been tried, by masonry and wooden bulkheads. These have been effective where it only needed another "straw", but have generally been disastrous. Drainage by perforating the bulkhead is taught as a rudiment in retaining walls. Mr. Dillman.

Far apart as they may seem, there is much similarity in slides, retaining walls, and dams. The analysis is nearly identical, gravity, friction, and hydrostatic pressure. Sub-drainage will cure the slide, is necessary to the stability of the wall, and increases the safety of the dam.

All study is for the purpose of developing or properly applying principles. The result is education. The principle of slides is: Cause, water; Cure, drainage. There are no exceptions, though, at first sight, some may appear.

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THE SUBSIDENCE OF MUCK AND PEAT SOILS IN SOUTHERN LOUISIANA AND FLORIDA

Discussion.*

By William T. Lyle, Assoc. M. Am. Soc. C. E.

William T. Lyle,† Assoc. M. Am. Soc. C. E. (by letter).‡—An extensive deposit of muck and peat occupied 25% of the area of the tract set apart by the Essex County Park Commission in Newark, N. J., as Westside Park. This park covers six city blocks, and has an area of 24 acres. The western half of the park is high, and the eastern half low. In the latter part, especially to the southeast, there is a muck and peat deposit having a depth of 35 ft. the development of which was the most important feature of the park work. Mr. Lyle.

The general contract included the following operations. First, the entire site, with the exception of the bog, was stripped of its top soil. This was placed in two large piles with spiral drives. The necessary excavation and embankment was then made to bring the surface to sub-grade. On the site of the bog, the landscape architects, Olmsted Brothers, of Brookline, Mass., planned a large artificial pond involving the removal of muck and peat to the depth of 10 ft. Most of this material was used as filling on the prepared upland sub-grades and in the construction of a border-mound along Fourteenth Street. The remainder was hauled away to Branch Brook Park for use as a fertilizing top soil. To maintain a shore on the eastern side of the pond, the plans of the chief engineer, Howard J. Cole, M. Am. Soc. C. E., called for a timber bulkhead of piles which were driven close, with every fifth pile battered to act as a brace. In front of the bulkhead,

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* Discussion of the paper by Charles W. Okey, Assoc. M. Am. Soc. C. E., continued from December, 1917, *Proceedings*.

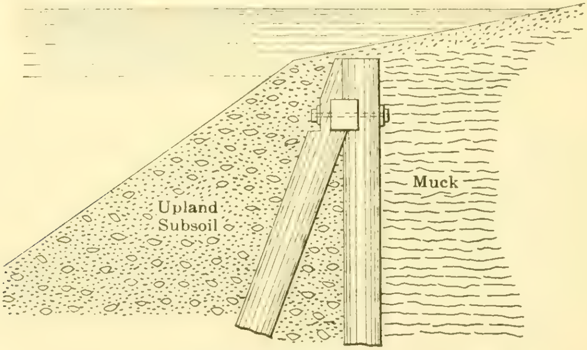
† Easton, Pa.

‡ Received by the Secretary, November 24th, 1917.

Mr. Lyle. that is, on the pond side, good upland sub-soil was deposited. After settlement, this fill was trued up to the finished surfaces. The muck and peat were removed from the pond by tram, by wagon, by derrick, and by cableway.

The other main contract items were sewers, water pipes, paths, and retaining walls.

The upper layer of material removed from the lake was black, and is defined as "muck" by Mr. Okey. Its depth was from 4 to 5 ft. It was composed mainly of vegetable matter, but contained a little mineral matter also. The surface of the deposit, before the work was begun, was sufficiently firm to support a loaded wagon. After being dried in an oven, the muck could be burned like coal. Below it there was a brown colored peat, which, in its natural condition, weighed but little more than water. In it could be seen the imprint of the leaves of prehistoric trees, and it contained many well-preserved roots or "snags". The peat was found to be very tenacious of its water, even when piled on the shore, but, when dried in an oven, proved to be good fuel.



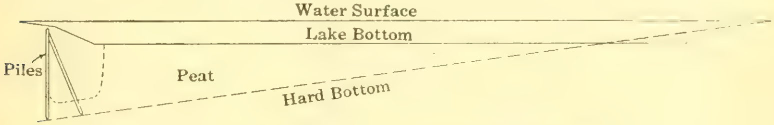
TIMBER BULKHEAD AND SUBSOIL FILLING TO FORM ARTIFICIAL SHORE.

FIG. 20.

To construct the bulkhead, 23 000 lin. ft. of piles were driven. In the preliminary investigation which led up to the design, soundings were made along the proposed shore line and at various other places. This work was done by one man. The method was as follows: A hole, 1 ft. or more deep, was first dug in the crust, and a 5-ft. length of gas pipe was driven down with a maul. To it was coupled another length, which was driven in the same manner, and so on until hard bottom was reached. The pipe was raised with a chain and a lever by the man who did the driving. It contained a core of the material through which the sounding rod had passed, with a short core of white sand at the bottom. The same pipe was used repeatedly.

During the construction, which took place in 1899 and 1900, and also after the completion of the work, the following interesting observations were made. Mr. Lyle.

The water level shown on the plan, which was set at 196.0, for reasons of economy, has not been maintained, its average value being about 3 ft. lower. As a consequence, the soil to the east and south of the shore line has drained into the lake. Back of the bulkhead, at a place where the depth to the hard sub-stratum is from 30 to 35 ft., the settlement since the completion of the work is about 0.75 ft. In terms of the distance down to the water-table, this settlement is about 15 per cent. There had been a probable equal settlement during construction, thus making the total shrinkage about 30 per cent. In making the fill in front of the timber bulkhead, the engineers were reasonably sure that equilibrium would be attained before the deposited material reached solid bottom. This was found to be the case. The upland soil dumped over the bulkhead displaced an equal volume of peat which had to be removed by cableway. In order to guarantee a more or less stable equilibrium, the fill was carried about 3 ft. above the finished grade, and after a few months the surplus material was removed in bringing the fill to the finished surfaces. Since the completion of the work, however, there has been a settlement of about 2 ft., leaving the tops of the piles exposed above the beach.



TYPICAL SECTION OF POND AT WESTSIDE PARK.

FIG. 21.

Another interesting phenomenon was noticed when trenches were opened in the muck. A trench 4 or 5 ft. deep and 2½ ft. wide could easily be excavated without sheathing, but, if left open for more than 12 hours, would gradually close, the sides remaining as vertical surfaces. Ditches 2½ ft. wide in the afternoon were sometimes found to be only 6 in. wide the next morning.

Where muck and peat were used on upland sub-grades, allowance was made for shrinkage, and top soil was not applied until the wet material had been exposed to the air for several weeks. Not more than 2 ft. of soft material was ordinarily used. There has been but little settlement. As was expected, the peat was incapable of supporting vegetable life until decomposition had taken place. It then gave rise to luxuriant growths.

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A BRIEF REVIEW OF TRIGONOMETRICAL MATHEMATICAL TABLES, AND A CONTEMPLATION OF THE SPECIFICATIONS FOR TRIGONOMETRICAL TABLES FOR GENERAL USE

Discussion.*

By Horace Andrews, M. Am. Soc. C. E.

Mr. Andrews.

Horace Andrews,† M. Am. Soc. C. E. (by letter).‡—The author indicates the need of tables such as those mentioned under his Subheading *g*, which were left incomplete by the death of Professor Jordan, but which, in all probability, would have been completed, as he had planned, under more favorable conditions for such work. The author designs to have the computing machine supplant the usual tables of logarithms of numbers, and this will reduce materially the size of his proposed tables.

Referring to Mr. Eberly's numbered propositions, the writer would make the following remarks and suggestions:

Proposition I.—The use of the 90° division to the quadrant cannot be regarded as quite general, though it is nearly so. It may be expedient to adhere to this usage, but the absolute necessity for doing so is not apparent. There are many tables which are based on the division of the quadrant into 100 parts, or centesimal degrees—frequently indicated by a small letter *g*. These tables, for the most part, are from French, German, and Italian sources. Instrument makers in Europe quite generally advertise their readiness to furnish circles with the 100° division to the quadrant. It should not be forgotten that the metrical

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* Discussion of the paper by Virgil A. Eberly, Assoc. M. Am. Soc. C. E., continued from December, 1917, *Proceedings*.

† Cocoanut Grove, Fla.

‡ Received by the Secretary, December 10th, 1917.

Mr Andrews. system is based on a division of the earth's meridian quadrant into 100 centesimal degrees, each of the length of 100 km. Where the metrical system is in use, it is logical also to adopt the centesimal degree. In certain classes of work, the centesimal division has not only all the advantages pertaining to the decimally divided degree, enumerated by the author in his second proposition, but others arising from a quadrant of 100 parts, and a semicircle of 200 parts instead of 180 degrees. Professor Jordan* carries out a complete traverse computation in duplicate, with old and new divisions of the quadrant, and remarks that: "With the continued changing by ± 180° one is liable to three times as many errors of computation as with the continued changing by $\pm\ 200^{g}$." The convenience of having angles in the different quadrants easily located, as they are with the centesimal degree division, is at once apparent.

Proposition II.—The decimal division of the degree seems to have been proposed originally by Henry Briggs, and was used in his "Trigonometria Brittanica" published in 1633, after his death; but this division never seems to have had any extended use. It was revived in Bremiker's five-place tables, in 1872, apparently as a protest against the centesimal degree, for Bremiker remarks in his preface that both systems are arbitrary, and indicates that a preference might be had for a division of the entire circle into 1 000 parts as more logical, though he confesses that it might not be easy to have the division of the day into decimal hours adopted. The writer agrees with the author that the decimal division of the 90° to the quadrant has attractions, but, many years ago, when he endeavored to make use of Bremiker's tables, he found the difficulties too great in the changes continually made necessary in using other tables, namely, the Ephemeris, where the sexagesimal division must be used first and then a conversion made into the decimal.

The writer is of the opinion that the change from sexagesimal to decimal division of the degree will be more difficult than the introduction of the metric system of weights and measures, and if at any time the latter is to be adopted, it would be more easy to use the centesimal degree than that it would be to adopt a decimally divided degree of one-ninetieth part of the quadrant.

Proposition III.—The author does not indicate clearly the process of interpolation that he prefers, that is, whether he would use the small marginal tables of proportional parts, usual in tables of logarithms, or whether he prefers to give only differences and rely on the slide-rule for working out the proportion, which is the process favored by Jordan, and may be more easily and quickly applied to the larger differences existing in seven-place tables.

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* "Vermessungskünde", 2d. ed., 1877.

Mr. Andrews

Proposition IV.—This may be open to question. Eight-place tables are now required for mathematical exactness in least-square adjustment of primary triangulation or other refined geodetic work; but, for the work usual in engineering, even where a very high degree of precision is sought, six places are almost always more than sufficient, and furnish a margin of precision sufficiently greater than that of the field measurements. As Bremiker points out, in his six-place tables, the numerical work of interpolation between tabular values is much abbreviated when the number of decimals used is reduced, the closeness between the arguments remaining the same as in the seven-place tables. For almost all work of an engineering nature, five-place tables are quite sufficiently precise. The degree of precision thus attainable is indicated in some of the editions of Gauss' five-place tables, which seem to have passed through a greater number of editions than any having a greater number of decimals. Any engineer having doubts as to the sufficiency of five places of decimals should carry out a few duplicate computations, using five places and seven places, and compare his results with the precision of his field measurements. If seven places should be chosen, as the author prefers, it would be very advisable to have editions with six places also available, on account of the greater ease of interpolation with the six-place table.

Proposition VI.—Thumb-indexing may be difficult of application to some tables where only a few pages are necessary; they also somewhat jeopardize the edges of a much-used book. Perhaps colored paper could be used to advantage—at least in some of the proposed tables—to facilitate their use, if for no other reason. It will be recalled that Babbage advocated the use of colored paper on other grounds; he considered that black on a white ground was a fatiguing combination for the eye, but it does not appear that any definite conclusion as to this was reached through the use of his tables on paper tinted yellow, brown, green, etc. Professor Gillespie, in his "Treatise on Land Surveying" (1855), had his tables printed on a yellowish-brown paper, following Babbage's principle. Merely for convenience in turning to a certain portion of a book, the use of colored paper, as is well known, is frequently adopted. This expedient would not seem to lessen the usefulness of a book of tables, and, if Babbage is correct, it might prove of value. Colored edges to tables were used in the "Tables de Logarithmes," Paris, 1868, of J. Dupuis, red edges being used on the tables of the circular functions.

Proposition VIII.—The mechanical execution of a book of tables subject to continuous and severe use is a matter of great importance. The book projected by the author might be furnished in paper covers and unstitched, as in many foreign books, so that those purchasers who wished to do so could have a strong hand-binding in place of the usual poorly attached "cases." The writer would suggest hand-sewing, all

Mr. Andrews.

along, on five bands or tapes—flexible sewing—on the outside of the sections; all bands to be strongly attached to the covers and the whole covered with a good grade of buckram or other durable fabric, in place of the inferior leathers generally used commercially. The thinness of sections in the folio make-up advocated by the author would also be conducive to flexibility. There is no reason for not adopting the same manner of folding sections in an octavo, if thought advisable.

As there is little likelihood at present of any change from the sexagesimal division of the degree, it would seem prudent to adhere to that method of division if the proposed tables are to have any extended use.

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THE HELL GATE ARCH BRIDGE AND APPROACHES OF THE NEW YORK CONNECTING RAILROAD OVER THE EAST RIVER IN NEW YORK CITY

Discussion.*

By Messrs. Charles Evan Fowler and Henry H. Quimby.

Charles Evan Fowler,† M. Am. Soc. C. E.—The speaker's acquaintance with Mr. Lindenthal and his work began about 30 years ago, and the genius displayed in his designs for the Seventh Avenue and Smithfield Street Bridges, in Pittsburgh, led one to expect the design by him of some great structure like the Hell Gate Arch. The speaker hopes that Mr. Lindenthal may live to see an even greater culmination of his career, by the building of the great suspension span proposed for the North River. Mr. Fowler.

The Seventh Street Bridge, in Pittsburgh, built in 1884, is a two-span, eye-bar, suspension bridge, with braced parallel chains, and was a milestone in the design of suspension bridges. The two main spans are 330 ft. each, and the side spans 165 ft. each, with a width of 42 ft.

The Smithfield Street Bridge, which is still in use, is a very striking structure, consisting of two Pauli truss spans, the longest and heaviest of this type in America.

That the younger members of the Profession may not forget to have pride in American bridge engineers, it is well to call to mind the work of the Dean of this branch of the Profession, the late C. Shaler Smith, M. Am. Soc. C. E. His Kentucky River High Bridge was a wonderful structure, with three 375-ft. spans, 275 ft. above the river, a continuous-span bridge, which, by the cutting of the chords to fix the points of contraflexure, became one of the first great canti-

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* Discussion of the paper by O. H. Ammann, M. Am. Soc. C. E., continued from December, 1917, *Proceedings*.

† New York City.

Mr. Fowler. lever bridges. The four river spans of his Lachine Bridge, over the St. Lawrence River, were at the same time an example of the most scientific bridge engineering and an altogether striking and beautiful structure. The main bridge had two 408-ft spans, with two 269-ft. side spans.

When this structure required rebuilding, within the last few years, in order to carry modern heavy loading, it was with regret that we saw that its outlines were not preserved. When Mr. Lindenthal was called on to replace High Bridge with a heavier structure, a few years ago, the speaker, for one, felt that a vote of thanks was due to him for preserving the original outline. His work on the bridges of New York City, although, unfortunately, hampered in many ways, is reflected in the completed Hell Gate Bridge, which is the first wholly creditable structure to be built here since the completion of the old Roebling Bridge.

To the speaker the outline of the structure is most pleasing. This is due not only to the smooth curve of the arch proper, but mostly to the reverse curve of the top chords near the towers. The combination resembles, and is as pleasing as, a similar combination of curves in the "Camelback Bridge" in the Imperial Palace grounds at Pekin, China. To the speaker, the latter is the most pleasing of Oriental bridges.

The sickle-shaped truss design, which was abandoned for the Hell Gate Arch, for reasons having to do mainly with erection, could hardly have been more pleasing in its architectural appearance.

The towers as built are plain and simple in design, but are in every way appropriate and in harmony with the great arch. The speaker's reason for calling attention to this is the hope that some artistic person in the New York City government or the Art Commission may some day succeed in getting the parapet, or "attic story" as it might be termed architecturally, added to the towers of the Roebling Bridge, as originally planned.

Many great bridges have been marred architecturally by the appearance of the approaches, but when one visits this structure at Hell Gate and views the great masonry approach piers in perspective, their pleasing and appropriate character is fully appreciated. The whole structure may be said to be the most complete lesson in bridge esthetics in America, and one of the best in the world. The proper consideration of simplicity, symmetry, harmony, and proportion in bridge design was first enunciated by the speaker in "Engineering Studies", and, as it has been elaborated in many subsequent writings and discussions, he will take time only to repeat that the failure to regard any one of these four fundamentals must lead in some degree to failure.

The Dusseldorf and Bonn Bridges are both notable examples, which have been referred to by Mr. Ammann, but the Bonn design, especially

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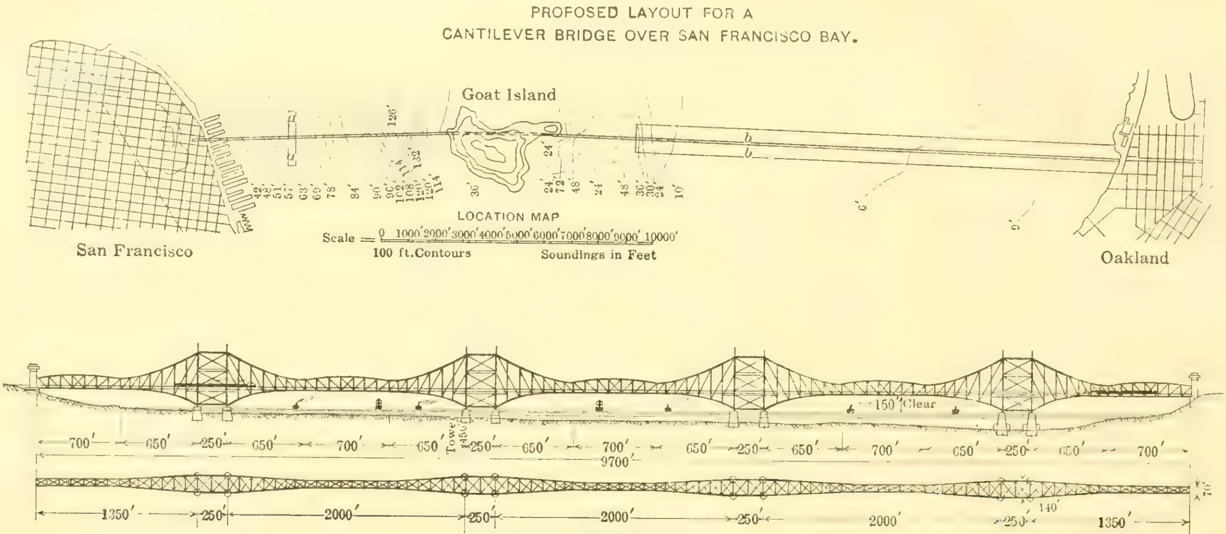

GENERAL PLAN AND ELEVATION

FIG. 56.

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when the bridge is seen in perspective, comes nearest to fulfilling all requirements, including one other, that of an unequal number of spans, the main span of 614 ft. and the side spans of 307 ft. There are so many notable arch bridges in France, both of masonry and steel, that it would be presumptuous in a limited discussion to do more than call to the attention of designers this great field of study. The great arch span at Oporto, with both upper and lower roadway, is perhaps the most striking of any of the examples mentioned by Mr. Ammann.

The great 840-ft. Clifton Arch at Niagara is one of the best examples in America, but it is with regret that one views the very inappropriate approach spans of the wonderful Grand Trunk Arch, its near-by neighbor. The Eads Bridge, across the Mississippi at St. Louis, with its three great steel arch spans of about 500 feet each, with simple, appropriate, and well-designed masonry approaches, answers all the basic requirements of an artistic design.

There are five designs of the Quebec crossing which should be preserved in the final monograph of that great bridge. First, the cantilever design of many years ago, by Brunles and Light, a 1 442-ft. span for which much of the credit was due to Professor Fidler. Second, the 1 800-ft. cantilever which failed, due to neglect to observe fundamental features of design for compression members, which had been discussed previously by the speaker's one-time assistant, the late Professor A. H. Heller, in his "Stresses in Structures". The outline of this cantilever design was one of the most pleasing ever prepared for the Quebec Bridge. Third, the design of the present structure, which is strictly utilitarian, although it is to be hoped that great pylons will be added at each end, and proper finials over the tower posts. Fourth, the design prepared by Charles Worthington, M. Am. Soc. C. E., for an 1 800-ft. deck arch with one hinge; and fifth, the Lindenthal suspension design, referred to by Mr. Ammann. The latter, curiously enough, is of the type of braced chains, originated by Professor Fidler, who was partly responsible for the first design, and which suspension type usually bears his name.

Attention is called to the service rendered to the Profession by the study often given in this way to designs of great bridges, even though they may never be utilized, which was the case with three of the notable designs at Quebec, and (up to the present) is true as regards a North River Bridge in New York City.

After some 25 years of study of the necessary features of a bridge across San Francisco Bay, it became apparent to the speaker, a few years ago—in common no doubt with many other engineers—that a bridge was a vital necessity. Without giving any lengthy description of the proposed main channel crossing, of three 2 000-ft. spans from Goat Island to Telegraph Hill, Fig. 56, one can judge from an inspec-

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tion of the outline as to how nearly it fulfils the requirements of simplicity, symmetry, harmony, and proportion. In a discussion of the paper by J. A. L. Waddell, M. Am. Soc. C. E., entitled "The Possibilities in Bridge Construction by the use of High-Alloy Steels", the speaker pointed out* that long-span bridges are seldom constructed from motives of economy, and enunciated six postulates that covered the basic principles leading to their construction. Considering this San Francisco design, it is apparent at once that the proposed arrangement is not the economical one, but that which is necessary owing to the great ocean commerce cared for by San Francisco Bay. This is the conclusion arrived at by the Chief of Engineers after the hearing before three members of the Corps of Engineers, constituting the Board, at San Francisco in August, 1917. This decision was, that any bridge constructed in certain portions of the Bay should have spans of not less than 1 800 ft., with a clearance of 210 ft. for a horizontal width of 800 ft. This can all be complied with in the proposed design.

The chord sections used for the compression members of great spans already built are of three types: the rectangular, as used at Quebec and elsewhere; the double box, as used for the Hell Gate Arch; and the cellular circular type, as used in the Forth Bridge. The first lacks economy and inherent rigidity, the second lacks economy, but the third seems to lack nothing, theoretically, but practically is a very expensive form to build and very difficult to join with other members.

The speaker has proposed a form for the San Francisco Bridge, a cellular octagonal section, Fig. 57, which is very economical, is inherently stiff, can be readily built by a shop in segments, and to which it is perfectly easy to connect other members in an efficient manner. It is hoped that this may prove of value in the construction of many long spans. For the 700-ft., or possibly 800-ft., suspended spans, there is proposed a new combination of web systems, which has been termed the "PK" system, it being a combination of the Petit and Kellogg sub-trussing, which serves admirably to carry both the upper and lower decks.

The normal increase in the cost of steel after the war, owing to the rapid depletion of raw materials, will place a time limit on the period within which great spans may be constructed, and, in a conversation with Mr. Lindenthal recently, he pointed out that this period would not be likely to extend beyond 30 years, or, say, 1950. Therefore it behooves engineers, not only to be more conservative in the use of steel, but also to be less prodigal; they should plan in every way to extend the time of depletion.

The use of such types of structures as will require the least weight of metal will be of great value, and, therefore, one may look for more wire cable suspension spans, and more continuous-span bridges, similar

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* *Transactions*, Am. Soc. C. E., Vol. LXXVII, pp. 43–49.

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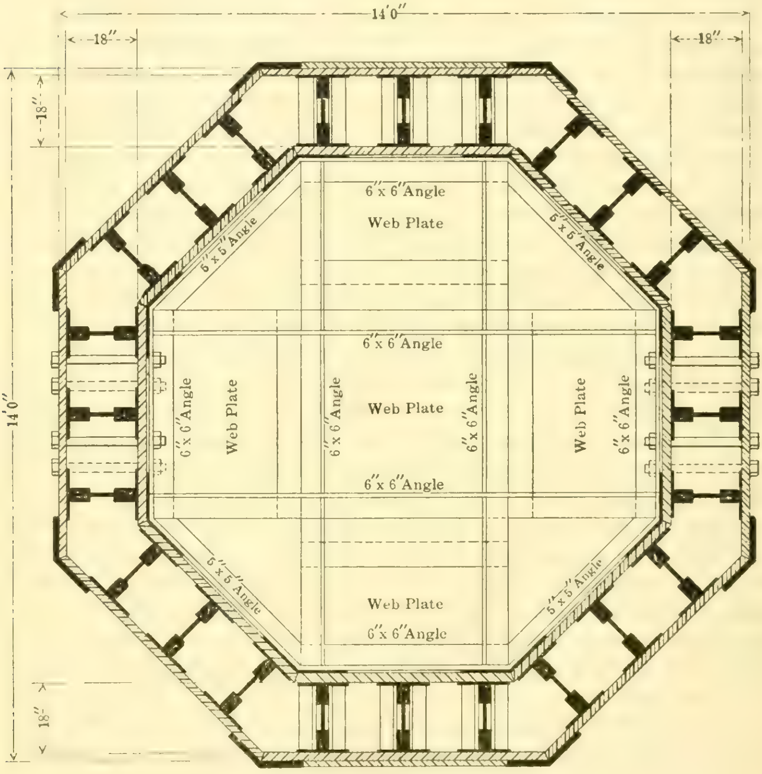
to the notable bridge just built by Mr. Lindenthal at Sciotoville over the Ohio River, with its two great spans of 750 ft. each. The necessity for saving tonnage recalls a letter received from the late Zenas King, of Cleveland, nearly 30 years ago. He said: "Any engineer can build a bridge if you give him plenty of money and plenty of iron, but it takes a genius to build a bridge with very little money and very little iron."



CHORD OF SAN FRANCISCO-OAKLAND BRIDGE.
FIG. 57.

Then, again, engineers must have better and more uniform carbon steels. The cost of making nickel steel, chrome-vanadium steel, and other high-alloy steels, must be reduced, so that for a given weight of metal, there may be from 50 to 100% of increased strength.

There may be found other steels, similar to the Mayari steel used in a recent long-span bridge; but such steels, at the same time, must have more uniformity of strength, and not have such a range as was

Mr. Fowler

shown in the tests for this bridge, where the variation was so great as to indicate that its future use would not be profitable.

When engineers obtain a cheaper high-test uniform steel, there is but one thing needed to feel safe in turning back from the present often ridiculous high factors of safety to the more economical ones they deserted a score of years ago: This is, to gain more confidence in the computed results of stresses, especially secondary stresses, and the paper by D. B. Steinman, Assoc. M. Am. Soc. C. E., on the measurement of the stresses in the Hell Gate Bridge is a great step forward. The Government, which is so rapidly becoming paternal in character, should require extensometer tests on all important structures to the end that engineers may eventually feel perfectly safe in designing all steel structures with very much greater unit stresses and a consequent enormous saving in steel consumption.

The specifications as to shop work are worthy of special study in connection with all designs for future structures of any importance whatever, and the clauses with reference to punching, reaming, and drilling are especially noteworthy to one who has spent years in the fabrication of steelwork. The data in regard to the driving of long rivets should be read with care, and great good would result from the application of these methods to all railway and highway bridges of importance. Unless the engineer has had occasion to rebuild some old bridges, he cannot realize how criminally careless the average bridge erector is in driving all rivets with a long grip.

This subject is of such great interest that it is impossible to close without congratulating all those having to do with the erection of the Hell Gate Arch on the unusual success of all the operations, although the care exercised in planning every step would lead one to expect the best results. The similarity of the method to that used for the Eads Arches at St Louis under the late Walter Katte, M. Am. Soc. C. E., should be noted, although the much lighter weights and shorter spans of that structure make it no more than a suggestion, as to how to handle such great weights as have to be dealt with in a great span like Hell Gate.

The remarkable extent of the foundations and the use of a series of caissons to take up the thrust of such a great arch, mark an epoch in deep foundations. Should the construction of the San Francisco Bridge be undertaken, one group of four piers will require founding in 130 ft. of water, and a somewhat new method of sinking open dredged caissons has been provided for, in order to prevent them from tipping. Such an accident occurred to one of the great cylindrical caissons of the Forth Bridge at South Queensferry. The caisson ring just above the cutting edge will be provided with a number of chambers or tanks, uniformly distributed around the circumference of the caisson. These tanks will be provided with sea valves for the admission of water, Mr. Fowler. the valves being operated from the surface. Another set of valves will be connected with air pipes connecting with compressors at the surface. Should the caisson tip, water will be forced out of the chambers on the low side and admitted to the chambers on the high side, thus serving to right it. The operation can be extended gradually from one chamber on each side to a number, or as many as necessary to overcome the list. Of course, care must be exercised to bring the caisson back to a vertical position gradually, and to meet the movement by a reversal of conditions in the opposing chambers. The term "ballmatic" has been applied to this type of pier, the name being coined by a combination of the words "ballast" and "pneumatic."

The speaker realizes that papers having such a wide scope as these, describing this great bridge, and the stress measurements of the members, will call forth a very extended discussion, and that lack of space will require their curtailment. Thus, many features that could be profitably considered will have to be omitted, and the speaker will close in the hope that others will cover many other points of value, and of vital importance for consideration, in the design of future long spans.

Mr. Quimby. HENRY H. QUIMBY,* M. AM. SOC. C. E.—In the presence of the magnificent achievement of this imposing monument, the product of the very highest grade of technical and practical skill in the world, through years of study under apparently ideal conditions, with *carte blanche* as to time and cost, and free play for fancy and cultivated taste, one hesitates to introduce a note of comment that may even seem like criticism. In the published writings on the work, however, in the paper as presented, and in Mr. Lindenthal's supplemental oral remarks, much emphasis was laid on the matter of appearance, and it seems that it was not so much economy as esthetic considerations which controlled in the selection of the type of structure in at least three of the divisions of the work—the main span, the viaduct approaches, and the Little Hell Gate Bridge. Wherefore, it is probable that the designers, masterly and successful as they are, will welcome a frank expression of judgment on their taste.

Esthetic considerations embrace the effect on the lay mind as well as on that of professionals; because of this, public Art Commissions are created to pass on technical construction—on the work of artists as well as that of mechanics—of architects as well as of engineers. It is desirable, therefore, to make a structure appear not only graceful but satisfyingly stable to the miscellaneous eye as well as to the trained and understanding scientific eye. One feature of the main span suggests these reflections. The end post of the spandrel bracing in bearing on the end pin is almost directly over the front face of the abutment support, and to the miscellaneous mind this post appears to be the end of the bridge—the span structure. The effect, when viewed from a point at right angles to the bridge, is to make it seem as if the truss is resting just on the edge of the bridge seat, and with the considerable space between it and the shaft of the abutment pier, the truss looks short for the span opening. Mr. Quimby

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* Philadelphia, Pa.

The earlier published plans showed the top chord terminating at the end post, leaving a gap between it and the shaft, which condition accentuated the impression of scantiness of length of truss. The subsequent extension of that chord into the shaft relieved this feeling and much improved the appearance. As a false member was thus inserted at the top, the improvement might have been continued by adding a panel, or a false diagonal, from the end pin to the shaft, but as the end post has no necessary relation to the end pin in its present location—which evidently was fixed to secure adequate distribution of bearing on the skewback—it would seem to have been better to reduce the gap by moving the post 3 or 4 ft. closer to the shaft, so that its direction would intersect with the direction of the thrust of the end lower chord member at a point nearer the skewback, and then give it a separate pin. This would not complicate the determination of stresses, and it would give the structure the appearance to everybody of adequate length and bearing on the bridge seat. The length of each panel and the theoretical length of the span would thereby be increased very slightly, but the angle of thrust is so steep that the stresses in the arch would probably not be increased sufficiently to constitute an objection to the change.

A view of the approach piers during their construction, and before any of the steel work was on them, gave some the impression of disproportionate massiveness compared with the spaces between them, and this feeling still continues with the superstructure in place. Would not such height and volume of masonry, in the case of the higher piers, more economically and more pleasingly support longer and heavier spans? We are not told whether the pier spacing was determined by economy of proportion between superstructure and substructure, or by right-of-way conditions. The exhibit of alternative designs with steel bents in itself justifies the type adopted and used, for the rocker bents—absolutely without a base in the side elevation—would give a very unpleasant feeling of instability. The ordinary public observer would recognize at once that somewhere something must be provided to make up for the palpable deficiency in longitudinal stability of the individual bents, and the Art Commission's objection to the steel designs shown is, of course, clear to all; but, was a trial made of a design of tapering steel towers—steel bents with buttresses—each stable in itself against longitudinal as well as transverse forces, and, if so, how did it compare in cost, including the capitalized cost of mainte-

Mr. Quimby. nance? The paper gives the reasons for not adopting concrete arches for the approaches, and the soundness of such reasons will probably not be questioned, but the appropriateness of that type of construction there has probably occurred to almost every interested observer.

One other feature of the work is of character and proportions that do not accord with the taste of some students of bridge architecture. This is the bridge over Little Hell Gate. The inverted bowstring trusses introduce a note that, although not really discordant, seems very outstanding, and, in dipping down so close to the water, they give the impression of superstructure depth disproportionate to the whole-structure height. The depth of construction at mid-span is quite appreciably more than half of the whole height of the structure above the water. The paper states that the trusses were made of the bowstring type so as to give additional clear height near the piers for vessels to pass—a somewhat unusual provision for navigation which generally prefers to give channel piers a wide berth. As the foundation here was on rock at a reasonable depth, it would seem that arches of steel, or even of concrete, might have been adopted as consistent and pleasing, and less obstructive to navigation. Was an arch design investigated, and, if so, how did it compare with the bowstring?

The design of the Bronx Kill Bridge, with inclined end posts at the abutments and vertical ones at the pier, suggests the case of more than one bridge where an original single span has been converted into two spans by building a pier under its middle after it had become inadequate. Presumably, the heels or counterweight trusses (the design of which is not found in the paper) will, when placed, remove the present disparity, but, as that may not be for many years, would it not have been worth while to make the trusses symmetrical in outline during the interim by inclining the pier ends, which is a common practice for the outer ends of bascule leaves.

The paper is an unusually satisfying one, both in the fact that it appears while the public and the professional interest in the remarkable feat is still fresh, and in that it discusses so freely the reasons for the various features of the design. The oral presentation of the subject by the author was also exceptionally felicitous, summarizing and supplementing the paper rather than repeating it by reading word for word, as is too often done with preprinted papers.

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STRESS MEASUREMENTS ON THE HELL GATE ARCH BRIDGE

Discussion*

By Messrs. Isidore Delson and Gustav Lindenthal.

Isidore Delson,† Assoc. M. Am. Soc. C. E.—Several years ago, the Bridge Department of New York City completed the work of strengthening the end spans of the Williamsburg Bridge across the East River. In connection with this work, a great many strain observations were made with the Howard extensometer, in co-operation with the U. S. Bureau of Standards. Mr. Delson.

The speaker desires to describe here especially one series of observations which seem to him of particularly striking interest, inasmuch as they actually assisted in the diagnosis of a perplexing situation, and pointed out the safe method of procedure in a difficult operation.

As indicated in Fig. 8, the end span trusses were supported in the lower chord, at Panel Point *L* 29, by 10-in. pins, by which the reaction was transmitted to the main, that is, suspension, span of the bridge through the panel triangle, *L* 29-*U* 30-*L* 30, containing the tension diagonal, *L* 29-*U* 30. As a part of the reconstruction, it was required to relieve these pins of their loads, to remove the pins, and then replace them by others of greater diameter.

At each truss a new panel triangle (*U* 29-*L* 30-*U* 30), containing the compression diagonal, *U* 29-*L* 30, was built out from the main span. The vertical end posts, *U* 29-*L* 29, of the end span trusses were connected to a new overhead transverse girder, *G*, which was supported by cast-steel blocks and wedges on the new panel points.

The relief of the pins was effected by wedging up the girder, *G*, from the new points of support, and the end spans were thus made to

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* Discussion of the paper by D. B. Steinman, Assoc. M. Am. Soc. C. E., continued from December, 1917, *Proceedings*.

† New York City.

Mr. Delson.

hang from that girder. As the old tension diagonals were being relieved of tension, the new diagonals were being compressed.

Extensometer points had been established on the old tension diagonal, and, also, on the new members before their erection.

It was determined by computation that the girder, *G* (and the trusses hung from it), would have to be wedged up ¾ in., in order to relieve the pins of the dead load re-action. However, when this wedging was effected, the pins absolutely refused to budge. The wedging was then increased to 1 in., and still the pins could not be made to move. The contractor apparently saw no other way but to continue this wedging process, and he was permitted to go as high as 1⅜ in., but without success.

All operations were followed up with extensometer observations on the members affected, but particularly on the diagonals. The results of these observations convinced the engineers of the Department that the contractor was on the wrong tack. Accordingly, the wedging-up process was stopped, and the condition was restored to the first established ¾-in. stage. Then the pins were removed by cutting them in halves. On their removal, there was not the slightest sensible dislocation of the members assembled on them, which verified the fact that no more nor less than the actual load on them was taken off.

The reason that the pins could not be rammed or pulled out was simply that they were rusted and scored too badly.

The following are the results of the extensometer readings for one of the old tension diagonals, and one of the new compression diagonals, at the Manhattan side, in the several stages of loading. These results are the averages of all readings in cross-section, of which there were six in the old diagonal and five in the new diagonal.

Old (tension) diagonal, *L* 29-*U* 30.—Cross-section, 98 sq. in., gross.—Computed dead-load stress in member at time of initial readings, 11 500 lbs. per sq. in.

Apparent relief of stress.—Averages of six readings in cross-section.

Stage of wedging..	¾ in.	1 in.	1⅜ in.	¾ in.	After removal of pin.
"Relief", in pounds per square inch..	11 300	13 600	16 600	11 500	11 600.

New (compression) diagonal, *U* 29-*L* 30.—Cross-section, 148 sq. in.—Computed stress for dead-load reaction, 6 400 lb. per sq. in.

Apparent stresses.—Averages of five readings in cross-section.

Stage of wedging..	¾ in.	1 in.	1⅜ in.	¾ in.	After removal of pin.
Compression, in pounds per square inch.	6 500	7 700	10 500	6 650	6 300.

Mr. Delson

Attention is called, not only to the close agreement of the computed stresses with those disclosed in the $\frac{3}{4}$-in. stage, but also to the fact that, after the pins were removed, there was no change in the stresses of the members, showing that just the exact amount of wedging had been applied.

It should be noted that the series here presented is rather exceptional, and that such good results may not always be expected from the extensometer; but, even where results are not so satisfactory, they, as a rule, would be close enough to help greatly in arriving at a correct judgment of conditions for all practical purposes.

Mr. Lindentha

GUSTAV LINDENTHAL,* M. AM. SOC. C. E.—A few words may be added to this able paper as to the speaker's reasons for having the erection stresses measured, as related by the author. He wanted to ascertain what, if any, bending stresses remained in the trusses after erection.

The speaker had in mind that, during the erection of the St. Louis Arch Bridge (built by the late J. B. Eads and Henry Flad, Members, Am. Soc. C. E., in 1870-74), which was the first instance of erecting steel arches by the cantilever method, the actual erection stresses varied considerably from the computed ones. During erection, the fixed ends of the arch ribs subjected the latter to temperature stresses which could not be regulated automatically. Men had to watch and adjust continuously, day and night, the pressure on the hydraulic jacks under the erection-towers on the piers in order to prevent overstressing the arch ribs. With every care, the adjustment could not always be done promptly, and so it happened that the secondary stresses, resulting from the bending of the ribs during erection and after the closing of the arches, remained largely unknown. That they were not negligible was shown by the fact that after erection one of the steel tubes forming the chords broke at the joint (and was replaced).

In addition to the bending stresses from erection and temperature changes are the secondary stresses from live load. These stresses must also be quite large in the St. Louis Bridge from the alternating flattening and bulging of the ribs at the quarters. An incidental effect of this is the creeping of the rails (each track is carried by two ribs) in the direction of the traffic to the extent of 12 in. per day. Another is the excessive straining of the cross-diagonals between the ribs, when one pair of ribs flattens and the other pair bulges under meeting trains. That this bridge has stood these extraordinary strains thus far without failure is proof of the excellent quality and elasticity of the crucible steel in the chords. If the strains in them could be measured (which they cannot, because the steel staves are enclosed in an envelope of wrought iron, and are not "get-at-able"), it would be a most instructive guide in other arch designs.

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* New York City.

Mr. ndenthal

In the design for the Hell Gate Arch, the speaker desired to minimize as much as possible the secondary stresses (from change of form). One way of doing this was by having the trusses stiff.

By making the arch deep at the quarters and three-hinged for dead load (which in this case is 40% greater than the live load) and two-hinged for live load, it could be arranged to avoid reversal stresses in the bottom chord altogether, and to keep the range (about 8 000 lb.) of unit stresses from minimum to maximum compression to within one-fourth of the elastic limit for compression on the gross net section.

A further means of minimizing the secondary stresses in the bottom chord was by providing against excessive edge pressures at the joints, as described by the author and also by Mr. Ammann.

In this respect, the Hell Gate Bridge is the antithesis of the St. Louis Arch Bridge with its tube sections and sleeve connections which are more subject to large edge pressures than, for instance, the full contact riveted splices in the shallow ribs of the Clifton Arch Bridge at Niagara Falls, which was likewise erected by cantilevering.

The object of the strain measurements, as related by the author, was fully attained. There are no unknown stresses in the Hell Gate Arch structure.

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CONSTRUCTION PROBLEMS OF THE MANHATTAN-BRONX, AND LEXINGTON AVENUE SUBWAY JUNCTION AND QUEENSBOROUGH TUNNEL CONNECTIONS

Discussion*

BY MESSRS. JOHN HAYS MYERS, CLARENCE E. CARPENTER, AND ROBERT A. SHAILER.

JOHN HAYS MYERS,† ASSOC. M. AM. SOC. C. E.—It is well that some one has placed on record a description of the work done in connecting the new Lexington Avenue Subway with the existing subway on Park Avenue, as well as of that incidental thereto. Much of it was done either under, over, or alongside what is without exception the densest railroad traffic in the world. In fact, the men in charge of operation speak of the tracks as being "saturated with trains." Although the problems met are rare, and peculiar to construction work carried on near moving trains, nevertheless, the principles involved and the methods used in solving these problems are well worthy of record. The author, therefore, deserves the thanks of his fellow-engineers for contributing this paper to the *Transactions* of the Society. Mr. Myers.

It is to be regretted, however, that he did not go into more detail because much more could have been written, with profit to the Profession, on this interesting piece of construction and on the methods devised and carried out so successfully. The speaker desires, therefore, to amplify certain matters contained in the paper and to bring out others which the author has not mentioned.

The engineers of the Public Service Commission realized before the contract was advertised that, to use the language of the author, the

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* This discussion (of the paper by George Perrine, M. Am. Soc. C. E., published in November, 1917, *Proceedings*, and presented at the meeting of December 19th, 1917) is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† New York City.

Mr. Myers. work involved was not by any means, "the standard construction in the New York subways." Therefore, much study was given to drawing up the contract, writing the specifications, and making the plans. That the time devoted to this study was well spent is shown by the fact that the work has been completed with few and minor departures from the contract plans, and that few questions have arisen which were not covered by the provisions of the contract.

The author's remark that the standard construction in the New York subways will not be dealt with in this paper has apparently precluded any reference to the Diagonal Station proper, other than to the method of excavating, on page 1898.* The Diagonal Station, so-called because of its location diagonally across the block east of Park Avenue between 41st and 42d Streets, is anything but standard subway construction. Although, as far as subway traffic is concerned, it is an ordinary two-island-platform station, similar to the present Grand Central Subway Station, its foundations, columns, and roof are designed so as to permit of placing above it a tall and heavy building, in order that the property condemned by the City of New York, 197 ft. 6 in. on Park Avenue and 230 ft. on 41st and 42d Streets, may be fully utilized for building purposes. To accomplish this, special attention was given to the foundations and to the design of grillages, columns, and roof members, members of extra strength being disposed so as to anticipate, as far as possible, the needs of any future building operations. Where a building column, because of its location, could not be carried directly on one of the station columns, heavy twin girders were introduced in the station roof to take the load of such column and carry it to two of the station columns.

The paragraph on sewers, on page 1898,* refers to the sewer construction beneath the subway at 41st Street and eastward under that street. Some sewer work was done, also, on the east side of Park Avenue, between 41st and 42d Streets, which continued northwestward under 42d Street to a point near Vanderbilt Avenue. It was first planned to build the Park Avenue sewer on the west side of the avenue, but, owing to the fact that it would have necessitated tunneling adjacent to the Hotel Belmont, in what was likely to be shattered rock beneath the floor of the existing south-bound Park Avenue Subway, the Commission's engineers changed the plan, and the sewer was built on the east side. A portion of the excavation consisted merely of a trench in rock below the general level of the excavation for the Diagonal Station. North of the excavation for the Diagonal Station, this sewer was built in tunnel and, when put in service, permitted the contractor to discontinue the use of the sewer by-pass which the author mentions in connection with his description of the large shaft connecting with the Queensborough Subway beneath 42d Street. Mr. Myers.

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* *Proceedings*, Am. Soc. C. E., November, 1917.

The references to duct lines, on pages 1898 and 1901, do not bring out the fact that the existing duct lines between the tracks in the north- and south-bound Park Avenue tunnels were a vital link in the subway operation, inasmuch as they carried cables which furnished power for both operation and lighting. Realizing this, the engineers of the Commission provided in the contract that, in addition to building the new duct lines which the author describes, the contractor should draw into these lines all necessary cables to replace those which were removed from the existing tunnels. This work was accomplished successfully without any interruption of train service. The contract provided that payment for this cable work should be upon a cost-plus-percentage basis.

The author states that the duct line near Fifth Avenue was built on account of the change in the tracks in 42d Street in front of the Grand Central Terminal. It would be clearer, perhaps, to say that this duct line was built because, in changing these tracks, or rather extending them eastward to form a stub-end terminal, the side-wall of the existing subway was removed and with it the duct bank which carried the power cables. The purpose of the duct line at Fifth Avenue was to make a connection between the lines on the north side of the 42d Street Subway and those on the south side, and thereby permit of carrying cables past the gap in the duct line, resulting from the removal of this side-wall. The new duct line was built by tunneling beneath 42d Street east of Fifth Avenue.

On pages 1901 to 1905 the author describes the very successful work of lowering the grade of the Steinway Tunnel tubes and converting them into a wide tunnel containing two tracks with an island platform. It should be recorded here that this was similar to a piece of work carried on previously by the same contractors in a part of the Queensborough Subway under 42d Street east of First Avenue. This work is very well described and illustrated in a paper* by Mr. Melville S. Miller, the engineer in charge of that work as well as of the Queensborough Subway work described by the author.

The author describes, on page 1911,† what he terms the "half arch construction." He first describes and illustrates quite fully the contract plans covering this portion of the work, and then the modifications of these plans and the method of executing them. The modifications proposed by the contractor are no doubt an improvement on those shown by the contract drawings. The design is similar, to those shown in the contract, the improvement consisting principally in the provision that no work was to be done over one of the existing tracks

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* *Public Service Record,* May, 1915.

† *Proceedings,* Am. Soc. C. E., November, 1917.

Mr. Myers. where the half arch was left in place. Furthermore, by raising the roof members to receive the thrust of this half arch, these members were removed farther from the tops of the cars, and the insertion of a shield permitted the operation of the trains over the regular tracks without routing them temporarily over other tracks by cross-overs. It should be remembered, however, that the design shown in the contract plans was based on a similar design made by the Commission's Engineering Corps and carried out successfully by the same contractor at the 168th Street and 191st Street Subway Stations. In these cases, the old tunnel arch was carried on new steel members placed beneath it, and the side-wall supporting the arch was removed to permit of the introduction of new or extended platforms.

In referring to the sequence of operations illustrated in Fig. 14, the author does not bring out the fact that, in Operation No. 1, namely, the driving of a longitudinal drift parallel to the existing tunnels, the elevation of the bottom of this drift was fixed so that the material which took the thrust of the arch would not be removed until, by Operations Nos. 2, 3, and 4, the greater part of this thrust had been removed. In removing the material and the tunnel arch, it was first intended to do it in alternate bands, leaving the intervening material in place. This, however, did not prove very successful, and it was found that, instead of removing the material in alternate bands or cross-drifts, it could be removed in successive bands, that is, the rock overlying the existing tunnel was removed in bands ordinarily not exceeding 7 ft. in width. The new structure, consisting of steel roof beams with concrete between, was then built in this space and the overlying material was caught up on the concrete before another band of material was removed. In this way, the subway trains were never exposed for a distance of more than 11 ft., and ordinarily not more than 7 ft. As a rule, the rock spanning this space between the new structure and the old arch required no support. In the few cases where it was thought that some of it might fall, it was readily kept in place by temporary longitudinal needles with one end resting on the completed structure and the other on the arch which had not yet been removed.

In the paragraph headed "Excavation", the speaker believes that the author, in referring to the portion of the work in Park Avenue between 42d and 40th Streets, meant to say "42d and 41st Streets", because the open-cut work in Park Avenue extended, roughly speaking, from a point south of 42d Street to a point somewhat south of 41st Street. This paragraph gives the impression that the south-bound local track was the only one where tunneling methods were used, although the difficult work which the speaker has just mentioned was carried on by such methods under Park Avenue south and north of 40th Street.

Mr. Myers.

The very complete diagram, Fig. 1, shows the location of the shaft used to carry on the express tunnel work on Park Avenue north and south of 40th Street. This shaft is interesting from the fact that its east and west dimensions were limited, its westerly limit near the surface of Park Avenue being determined by the wall of the tunnel through which the Park Avenue surface cars run, and near its bottom its easterly limit was determined by the wall of the existing north-bound tunnel. The excellent cross-section of the tunnels under Park Avenue, Fig. 20, illustrates these limits very well.

On page 1915,* the author speaks of the erection of the steel in the "half arch section". As the new tracks approached the existing ones, the space in which steel could be handled became more confined and, in some parts of this work, two hoisting engines were used to erect this steel, one being placed in the finished work and the other in the drift marked "Operation No. 1" in Fig. 14.

The author, in describing the "half arch section", goes into considerable detail in a discussion of the contract plans, and then shows how these plans were modified in carrying on the work. It is to be regretted that he did not treat, in a similar way, the construction of the south-bound local and express tracks under the present subway, and the rebuilding of the present north-bound structure, which he describes on pages 1925 to 1935.* He gives the design, as shown on the contract plans, but does not give drawings illustrating the work as actually carried out. The difference in the plans, however, is not great.

The possibility of readily building what constitutes a plate-girder bridge to carry the existing tracks over the new tracks passing beneath them was realized in getting up the contract plans. It was also realized that modifications in detail might be asked for by the successful bidder, and inasmuch as it meant the redistribution of practically the same tonnage of steel, it was thought that the plans were sufficiently comprehensive to permit of intelligent bidding.

On page 1928,* the author states that when the drift of the south-bound local had passed the subway structure, it was widened to the full size of the new sections. Figs. 25 and 26 illustrate this point, and indicate that the south-bound local tunnel passed through a duct manhole or splicing chamber on the west side of the existing structure near 41st Street. The bottom of this manhole was below the general floor level of the existing tunnel, and contained live power cables, and, until these cables could be removed, it was necessary to carry the south-bound local tunnel in a bottom heading. Figs. 25 and 26 do not show the walls of the vault of the Hotel Belmont, which walls followed the west curb of Park Avenue and the center line of 41st

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* *Proceedings*, Am. Soc. C. E., November, 1917.

Mr. Myers. Street. The southeast corner of this vault was about at the west line of the south-bound tunnel. As a matter of fact, the brickwork of these walls was uncovered in driving this tunnel, but the work was carried by them without damage to them or to the duct manhole and the cables in it.

The speaker thinks it proper to make mention here of the great value in this work of the records of the original subway work done in this neighborhood. From them, the Commission's engineers were able to predict with considerable accuracy what would be encountered in the way of construction and of material to be excavated.

In reference to Fig. 33, showing the method of erecting the express tunnel under Park Avenue, it should be pointed out that this design was well adapted to sectional construction. It is practically the same as that used in the construction of parts of the express tracks beneath Lexington Avenue, which work was described in a paper* by Israel V. Werbin, Assoc. M. Am. Soc. C. E. From a theoretical viewpoint, the question might be asked: When half of this structure is built, what balances the thrust of the arch? The speaker's theory with regard to this is that unless the rock is "heavy", there is little or no thrust; but, in any event, by building first what the author terms the "umbrella", the concrete engages with the roughness of the rock overhead and thus takes up what thrust there is, although it is possible, in using this construction, to put in temporary struts between the "umbrella" and the unexcavated rock on the other side of the tunnel until such time as the remaining arch is completed.

It would be improper if mention were not made of the use of the small drill commonly known on the work as the "Jap". In carrying the new tracks beneath the existing ones, the author refers to sinking pits or shafts, or else stoping them up from below, in which to erect various columns. In this work and in excavating rock very close to the completed structure, these drills were of very great advantage. It is difficult to imagine that it would have been possible to do this work with the old tripod drill which was in common use about 15 years ago on the subway construction.

Mr. rpenter. CLARENCE E. CARPENTER,† ASSOC. M. AM. SOC. C. E.—The members of this Society should be congratulated on having presented to them a clear and concise description of the work of constructing the portion of the Lexington Avenue Subway south of the north side of 42d Street, including the connection of that subway with the present one in Park Avenue, and also the extension of the Queensborough Subway from a point about 100 ft. east of Lexington Avenue to Vanderbilt Avenue. Many of the members are doubtless familiar in a general way with the scope of this work, but its difficulties and hazardous character can

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* "Tunnel Work on Sections 8, 9, 10 and 11, Broadway-Lexington Avenue Subway, New York City," *Transactions*, Am. Soc. C. E., Vol. LXXXI, p. 341.

† Yonkers, N. Y.

Mr. Carpenter

only be realized by examining the plans and considering the conditions under which it was done. It may be well to call attention to the fact that 1908 trains pass through the subway every week day, over the portion which was reconstructed in Park Avenue, carrying about 1 000 000 passengers. The interval between trains on each of the four tracks during the rush hours is 1 min. 48 sec., and the longest interval between trains on the local tracks, which occurs for a few hours after midnight, is 7½ min.

The speaker's position, as Engineer of Maintenance of Way with the Interborough Rapid Transit Company, has made it necessary for him to follow the progress of many of the large sub-surface construction jobs under way in New York City during the past 12 years, much of this work having been carried on in close proximity to either the elevated or subway lines. He can say, without hesitation, that not one of the jobs he has seen has seemed to him to be so difficult to perform at a reasonable cost and with safety to the traveling public as the one under consideration. The speaker does not know what the contractor's expenditures are, but he can state that the work has been done safely and well. This satisfactory result was only obtained by the closest attention to details, the exercise of good judgment, and the full co-operation of the operating men of the Interborough Rapid Transit Company.

The contractor's engineers deserve credit for suggesting the "Half Arch Construction", which, as compared with the original design for that portion, made the work much simpler. In the case of the express track connections, the removal of only the half of the arch over the old express tracks was required, and on these tracks trains are not run between about 1.00 and 5.30 A. M.

The shield erected on the interior of the old tunnel was an ingenious design, and worked out very well. The author states that it was not designed to support large masses of displaced concrete. As a matter of fact, it was made about as strong as the space would permit. The clearance between the shield and the edge of a car roof was so small that, as an added precaution, a steel plate was mounted on the inside of the shield, longitudinally with the tunnel, in order to present a continuous smooth surface on which the corner of the car roof would slide if a car spring should break. The manner of setting and anchoring the bottom of the steel angle ribs was also given close attention, for, if displaced, they might have come in contact with the third rail. Such an occurrence would cause a heavy ground, and possibly set fire to the wooden shield.

The change of the plate-girder design to the standard construction of the old subway, where the new subway tracks cross under the old north-bound tunnel, facilitated the work very much. The heavy plate girders designed for the roof of the old tunnel were placed in the floor of that tunnel, where they could be handled, and where they

Mr. rpenter. are used to support the I-beams, which were placed one by one under the track as the concrete invert was removed. The shield built around the interior of the old north-bound tunnel at this location differed somewhat from that erected for the "Half Arch Construction". Center supporting posts between the tracks could not be used, as they would interfere with the placing of the heavy girders previously referred to; consequently, the horizontal top portion of the shield was suspended by bolts from the girders supporting the street decking. The top of the shield consisted of 6 by 10-in. wooden beams, placed in pairs, and about 6 ft. from center to center, on which were laid two courses of 2-in. plank. Each pair of beams was supported by three suspender bolts, $1\frac{1}{4}$ in. in diameter, one at each end of the beam, and one in the center.

The author has referred to the reconstruction of the floor of the old subway under the north-bound local track and the temporary support of that track designed to permit of lowering the track quickly to conform to the grade required to enter the new Grand Central Station of the Lexington Avenue line at the same elevation as the three other tracks at that station. The speaker does not contemplate lowering the track, but plans to divert the north-bound local trains to the north-bound express track between 33d Street and the new Grand Central Station, during the period when express trains are not run. The local track will then be taken up and relaid to the new grade, using new rails which have previously been curved to suit the new alignment and having the new standard section.

One of the main reasons for the success of this work was the method of excavating only as much as would permit of the erection of an individual steel member which was promptly placed in position and used to support the load it was designed to carry. This method insured the safety of the subway, and made it unnecessary to use a large quantity of timber falsework.

Mr. Shailer ROBERT A. SHAILER,* M. AM. SOC. C. E.—It is always a great satisfaction to the engineer to have the difficulties of the construction work under his charge appreciated. The several members of the Society who have taken part in the discussion have the speaker's sincere thanks, and to Mr. Myers, especially, all are indebted for his elaboration of the paper.

The contractors have had the most hearty co-operation from the Public Service Engineers, and they deserve great credit for giving lines and grades under very trying conditions, due to subway trains passing constantly alongside and often directly over them. The surveys were made so accurately that there was no difficulty in joining the new steelwork to the steel previously erected by the New York Central Railroad Company, on the site of the Hotel Commodore, nor with the steelwork of the Queensborough Elevator Shaft.

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* New York City.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications.

DISCUSSION ON FINAL REPORT OF THE SPECIAL COMMITTEE ON CONCRETE AND REINFORCED CONCRETE*

BY W. K. HATT, M. AM. SOC. C. E.

H. K. HATT,† M. AM. SOC. C. E. (by letter).‡—The Special Committee has adopted a simple and safe treatment of the mechanics of the reinforced concrete flat slab. The moment coefficients resulting from this treatment are thought to be too large by many constructors. Some attempt to reduce these coefficients by bringing into the analysis certain poorly defined phrases and novel elements that are without experimental basis. Others bring into evidence the large number of tests of flat slab floors in buildings, which uniformly show a resisting moment, as determined by steel stresses under design loads, which is much smaller than those specified by the Committee. Mr. Hatt.

The writer wishes to record measured values of the internal moment, as measured by steel stresses for several tests, and to discuss the value of this evidence.

Such tests have usually been carried on by loading four panels of a floor to twice the designed live load plus the dead load, with measurements of the accompanying deformations in a portion of the steel bars. When the quantity and the depth of the steel are known, the internal resisting moment about the various sections may be computed.

The following records of tests are presented with a view to defining the extent of the discrepancy between the measured internal moment and the external load moment. The discrepancy is not peculiar to flat slabs, but is found in reinforced concrete beams.

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* Continued from October, 1917, *Proceedings*.

† Lafayette, Ind.

‡ Received by the Secretary, October 26th, and November 16th, 1917.

Mr. Hatt. A test of a single beam in Purdue Laboratory, with extensometer measurements of the steel, yielded the following:

Unit stress in steel.	Percentage of load moment in steel stresses.
2 600	16.5
16 300	74.4
21 800	81.5
27 200	86.5
39 300	95.5
44 700	98.1

The results of 333 tests of reinforced concrete beams with from 0.49 to 1.96% of reinforcement are given by Messrs. Humphrey and Losse.*

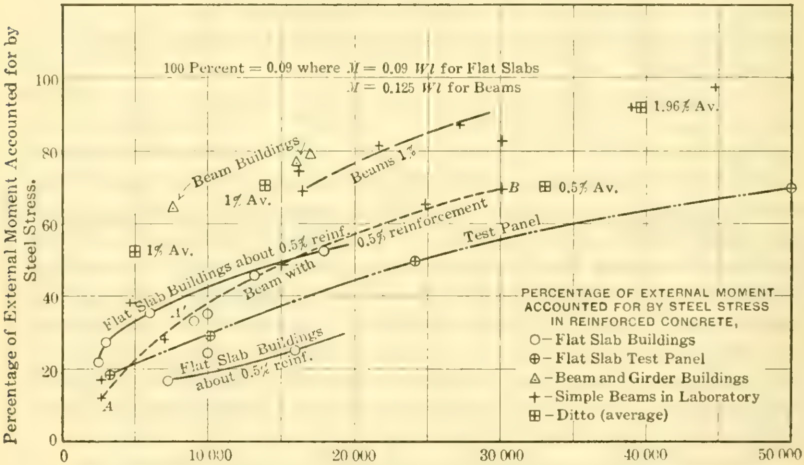

FIG. 27.

Those of the age of 4 weeks are platted in Fig. 28 to show the amount of external moment accounted for by steel stresses. Evidently, as we might expect, the rôle played by the steel is less important for lower percentages. Thus, at stresses of from 30 000 to 44 000 lb. per sq. in.:

Percentage of reinforcement.	Percentage of external moment.
0.49	73
1.96	92

The line $AA'B$ in Fig. 27 shows the relation between stress and steel moment for two beams with a low percentage of steel (0.499).

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* *Technologic Papers No. 2,* Bureau of Standards.

Mr. Hatt

A test of a sample beam in McGill Laboratory, with deformations of steel assumed to be the same as deformations of concrete measured on the surface of the beam, yielded the following*:

Unit stress in steel.	Percentage of load moment in steel stresses.
4 800	37.8
16 500	68.5
30 000	83.5
50 000	100.0

Eleven such tests at McGill showed an average percentage of load moment to be resident in steel stresses as follows:

5 000 lb. per sq. in. of steel stress, 52;
14 000 " " " " " " " 71.

Tests of continuous beams and girders of existing buildings are reported in the *Bulletin* of the Engineering Experiment Station of the University of Illinois, as follows:

	Steel stress.	Percentage of load moment in steel stresses.
Beam	16 000	77.0
Girder	17 000	79.0
Beam	7 500	64.0

Various tests of flat slab buildings, as reported in the *Bulletin 84* of the Engineering Experiment Station of the University of Illinois, and elsewhere, together with tests not yet published, are grouped in Table 8.

From an inspection of Fig. 27 and Table 8, it is evident that, even at steel stresses when the concrete is broken down in tension at some sections, there is a marked discrepancy between internal and external moment.

Thus, in No. 7, at 450 lb. load, where the slab is cracked clear down to the steel, which is stressed to 30 000 lb. per sq. in., only 46.4% of the external load moment, as fixed by Nichol's analysis, is accounted for. In this case there are no stress moments in corner columns to be added, and the load covered the structure completely.

Again, in Nos. 1-3, with a load of twice the live plus the dead load, with the concrete quite generally cracked, only 21.6% of the moment appears in the steel stresses. Here the columns at the corners of loaded panels contribute, and are not included in the steel moments, and the loaded areas are surrounded by unloaded panels.

As the steel stress increases, the percentage of moment resident in the steel increases also. As the percentage of reinforcement increases, the part played by the steel increases.

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* *Transactions,* Can. Soc. C. E., Vol. XXII, p. 245.

Mr. Hatt. The evidence at hand points, probably, to a more persistent operation of these tensile stresses in the case of flat slabs, with about one-half of 1% reinforcement, than in beam structures, which are more heavily reinforced.

Although the curve for beams with a small percentage of reinforcing is not greatly different from that of flat slabs, there is this real difference of condition. Below *A′* the beam is not cracked in tension, but the flat slabs in this region of the diagram are cracked at critical sections, at least down to the steel. There is also this difference, that, in the flat slabs, the deformations were measured on the steel, whereas, in the beams, they were measured on the surface of the concrete.

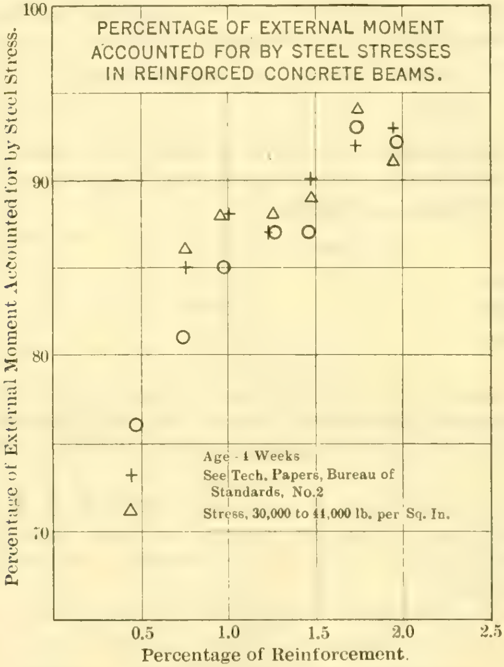

FIG. 28.

Individuals will no doubt attribute these remarkable discrepancies between steel internal moments, appearing in steel stresses, and external moments, to some other action than the tension in the concrete. The writer would rather look to the latter than to some poorly defined and unproved agency.

Mr. Hatt.

TABLE 8.—Results of Tests of Flat Slab Floors.

Moment Coefficients n where $M = nWl$, Accounted for by Measured Steel Stresses.

Building.	Load, in Pounds per Square Foot.		Number panels loaded.	Positive.		Negative.		Total Coefficient.	Percentage of:	
	Design.	Test.		Stress.	Coefficient.	Stress.	Coefficient.		Theory.	Joint Committee.
(1) Franks..............	250	739	2	10 100	0.0068	9 290	0.0149	0.0217	24.0	28.0
(2) Larkin.......... ...	250	738	2	16 000	0.0090	8 500	0.0135	0.0225	25.0	29.5
(3) Schultz..............	300	844	4	6 200	0.0038	7 100	0.0105	0.0143	15.8	19.0
			Average	....	0.0065	....	0.0130	0.0195	21.6	25.5
(4) Shredded Wheat......	125	191	9	....	0.0210	18 000	0.026	0.0470	52.2	61.8
(5) *A*....................	150	150	4	2 500	0.007	....	0.013	0.0200	22.2	26.3
	....	300	4	9 000	0.010	....	0.020	0.0300	33.3	39.4
	....	400	4	13 500	0.013	....	0.028	0.0410	45.5	54.0
(6) *B*....................	150	150	4	3 000	0.0104	....	0.0133	0.0237	26.3	31.2
	....	300	4	6 000	0.0140	....	0.0180	0.0320	35.5	42.1
	....	400	4	10 000	0.0152	....	0.0176	0.0328	36.3	43.1
(7) Test slabs............	150	150	All	....	....	....	....	0.0167	19.0	22.0
	....	300	All	....	....	....	....	0.0253	28.0	33.3
	....	450	All	....	....	....	....	0.0430	47.0	56.6
	....	600	All	....	....	....	....	0.0610	68.0	80.2
(8) Theory of Nichols ($c = 0.225\ l$)...........................				....	....	....	....	0.090	....	....
(9) Joint Committee..				....	0.029	....	0.047	0.076	....	....

Mr. Hatt. In either beam or flat slab structure, at ultimate loads producing a yield point in the steel and ultimate deformation in the concrete, the external moment and internal measured moment will agree.

We turn to ask if these tensile stresses in the concrete, which thus appear to operate at high steel stresses under high loads, may not receive some credit by the designer—either in the form of reduced moment coefficients or increased steel stresses. The Committee has frankly stated that it is reasonable to allow for the large breadth of structure in a flat slab, and the fact that the tensile resistance of the concrete is less affected by cracks, and so the coefficient has been reduced from 0.09 to 0.076. Commercial practice has been using 0.066. It would appear that there is a comfortable factor of safety in the lower of these.

It must be remembered that, by reason of shrinkage, and by temperature changes, this tensile resistance of the concrete may largely disappear, especially in exposed structures. Likewise, the implications of the phenomena of plasticity are not well understood. Then, too, steel placed to take negative moment may be depressed by careless placing, or by the weight of workmen or wheel-barrows, and the leverage lost.

Of course, the concrete must react in compression to the steel stresses, and also to the tensile stresses in the concrete. It will not do to fix moment coefficients with respect to steel stresses only, for then the compressive stresses will be much larger than we compute them to be. However, it is probable that concrete in flexure, as ordinarily designed, has a larger factor of safety in the compression flange than in tension.

Considerations of mechanics, of workmanship, of experience in construction, and the use of flat slab buildings, should all enter into the regulations for design. Public safety should first of all be sought, but the conservation of material should also be kept in mind. A factory or warehouse is a tool of industry, and the designer will wish to produce a useful, economical, and satisfactory tool that is safe to use.

There are a number of unknown elements in flat slab design—questions relating to distribution, to lintel beams, and wall columns, to proportions of drop panels, to design of marginal steel. In view of the extent of the investment in flat slab floors, the necessity for economical construction in these critical times, and the probable competition in manufacturing after the war, it would seem necessary to spend the $30 000 or $40 000 required to build and test thirty flat slab panels. A saving of 10% in the cost of the flat slab floors constructed up to the present time, due to a more accurate knowledge of their action, would represent an amount of $2 000 000.

The observation of deformations in the steel by skilled observers using the Berry extensometers is very accurate. In the earlier tests, Mr. Hatt.

the effect of changing temperatures on both the instruments and on the slab itself was not appreciated. The use of invar steel has done away with the changes of length of the instruments; but the changes in length of the reinforcing bars, due to changes of temperature of the surrounding concrete and the steel bars themselves, are important, especially at early loads. A change of 20° temperature has caused changes of length in the reinforcing bars equal to those occurring under the application of the load for which the floors were designed. Every precaution should be taken, therefore, to make the observations at such times as equal temperatures may be maintained, or to adjust properly the observations for temperature changes.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

WILLIAM WALTER MARR, M. Am. Soc. C. E.*

Died October 3d, 1917.

William Walter Marr was born on June 9th, 1876, in Chicago, Ill., and came of an old American family. He was educated in public and private schools in Chicago and at the University of Notre Dame, at South Bend, Ind., from which institution he was graduated as a Bachelor of Science in 1895. He took post-graduate work in 1896 for which he received the degree of C. E.

In 1897 he entered the service of the City of Chicago as an Assistant Engineer and for several years was employed in various capacities in charge of bridge repairs, water supply, harbor work, and tunnel construction, under the general charge of the City Engineer.

In 1902, Mr. Marr became Division Engineer for the Board of Local Improvements of the City of Chicago, in general charge of street paving work for the West Side.

In 1908, together with the writer, he formed the present civil engineering firm of Marr, Green and Company, of Chicago.

In 1914, he was appointed by Governor Dunne, a Democrat, as Chief State Highway Engineer, and, in 1917, was re-appointed to that position by the incoming Republican Governor Lowden. Under Mr. Marr's charge the State Department of Highways was practically re-organized and placed on a thoroughly efficient basis. Many millions of dollars' worth of work was planned and constructed. At the time of his death, he was engaged on far-reaching plans providing for the expenditure of some $60 000 000 for a State-wide improvement of roads in Illinois.

Mr. Marr had made a special study of municipal paving and country highways. He was widely recognized as an expert of the highest class in those lines, and his advice was in constant demand. He had made a magnificent record in public office, and his re-appointment to the position by Governor Lowden was recognition of this fact. He was widely known in Illinois and adjoining States for his splendid technical and executive ability, and was in continuous request as a speaker at Good Roads conventions and similar movements. The volume of work called for by his position was so large, and the demands on his time were so great, that he literally worked night and day. Though of good physique, he was of a nervous temperament, and the net result was a break-down. For months he had been failing, but was so interested in his work that he refused to quit. He died on October 3d, 1917, and is survived by a widow and four children.

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* Memoir prepared by P. E. Green, M. Am. Soc. C. E.

This is a brief outline of Mr. Marr's professional life; but it does scant justice to the man. Great-hearted, tolerant, and charitable Walter Marr! He was always helping some one, and never asking for a return; wise in the ways of the world, wonderfully intuitive, yet excusing and condoning the little mistakes and frailties of his fellow-men.

He had a keen, analytical mind, great imagination, and bold initiative, combined with ability to execute his ideas. He was endowed, further, with that gift, supposedly so rare among engineers, of ability to appreciate artistic things. He was a painter of no mean ability, and the writer, who had been his friend and associate for many years, wondered at times that he should have become an engineer and not an artist.

His funeral was almost a sermon in itself. Men nationally known were there, as were many of those more humble ones whom he had helped generously, but always secretly. It was only when his personal effects and memoranda were searched that some real idea was gained of his charity. There were literally dozens whom he had helped financially and otherwise, about whom no one knew, and the writer who used to wonder how it happened that, with his plain habits, he was so often "broke", understood at last.

He was a member of the Illinois Society of Engineers and Surveyors and of the Springfield Engineers' Society.

Mr. Marr was elected a Member of the American Society of Civil Engineers on February 2d, 1909.

NELSON JAMES WELTON, F. Am. Soc. C. E.*

Died June 5th, 1917.

Nelson James Welton was born on February 15th, 1829, in the Bucks Hill District of Waterbury, Conn., in the house which was held, by inheritance, by six generations of descendants of Richard Welton who is said to have been the first male child born in Waterbury.

Mr. Welton received his education in the district schools and the old Waterbury Academy, where he studied surveying and civil engineering. In 1850, with his appointment as County Surveyor of New Haven County, he began a career as a civil engineer which lasted for more than half a century.

From 1853 to 1885, he served as City Surveyor of Waterbury; he also had charge of the construction of that city's water-works, and was its General Manager for more than 30 years, his record for economy of operation being exceptional. When the city's first sewerage system was ordered to be built, Mr. Weldon was employed as Engineer in charge of its construction. In 1878, he was appointed a member of the Connecticut State Board of Civil Engineers, which Board was organized to inspect the reservoirs and dams in the State, and continued as a member until he resigned in 1902.

---

* Memoir prepared by the Secretary from information furnished by William G. Smith, Esq., Waterbury, Conn.

Aside from his engineering activities, Mr. Welton held many important public offices, serving as City Clerk from 1853 to 1858; Town Clerk from 1856 to 1863; and for twenty-eight years he was a Justice of the Peace. In 1859, he was elected a Judge of the Probate Court; in 1861, as Representative from Waterbury to the State General Assembly; in 1863-64, as Recorder of the City Court; and from 1867 to 1896 (with the exception of two years) he was President of the Board of Water Commissioners. In 1853, when the Riverside Cemetery Association was organized, he was made Superintendent, and had also served as its Treasurer since 1865.

Mr. Welton was greatly interested in many of Waterbury's public institutions, and rendered valuable service in securing the bequest for, and the establishment of, the Bronson Public Library in 1870. He was an Incorporator and a Director of the Waterbury Savings Bank, a Director of the Waterbury National Bank, and a member of the Corporation of and, for a time, Treasurer of St. Margaret's School for Girls.

He was a life long member of St. John's Protestant Episcopal Church, having been connected with its Sunday School for 52 years and having served as its Senior Warden from 1889 until his death. Mr. Welton was a Mason, a Knight Templar, and a Shriner.

He was a man of quiet nature, and fond of home life. He was also a good business man, one of his most marked characteristics being his sound, level-headed judgment. Having been widely known in Waterbury through his church, fraternity, and business associations, he was held in great respect and deep affection by those who knew him.

Mr. Welton was a Charter Member of the Connecticut Society of Civil Engineers, and was elected a Fellow of the American Society of Civil Engineers on January 20th, 1873.

PAPERS IN THIS NUMBER

"**VERIFICATION OF THE BAZIN WEIR FORMULA BY HYDRO-CHEMICAL GAUGINGS.**" FLOYD A. NAGLER. (To be presented Mar. 6th, 1918.)

PROGRESS REPORT OF THE SPECIAL COMMITTEE TO REPORT ON STRESSES IN RAILROAD TRACK.

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Discussion........Feb., Mar., Apr., May, Aug., Sept., Oct., 1917, Jan., 1918

"**Cement Joints for Cast-Iron Water Mains.**" CLARK H. SHAW........Mar., 1917
Discussion........May, Aug., "

"**Modern Practice in Wood Stave Pipe Design and Suggestions for Standard Specifications.**" J. F. PARTRIDGE........Apr., "
Discussion........Aug., Sept., Oct., "

"**Obstruction of Bridge Piers to the Flow of Water.**" FLOYD A. NAGLER..May, "
Discussion........Sept., Nov., 1917, Jan., 1918

"**The Three 15-Cubic Yard Dipper-Dredges, *Gamboa, Paraiso,* and *Cascadas,* as Supplied and Used on the Panama Canal.**" RAY W. BERDEAU........Aug., 1917
Discussion........Oct., Nov., "

"**Air Tanks on Pipe Lines.**" MINTON M. WARREN........Aug., "
Discussion........Oct., Nov., Dec., "

"**The Cape Cod Canal.**" WILLIAM BARCLAY PARSONS........Aug., "
Discussion........Nov., "

Progress Report of the Special Committee to Codify Present Practice on the Bearing Value of Soils for Foundations, etc........Aug., "
Discussion........Nov., "

"**Detention Reservoirs with Spillway Outlets as an Agency in Flood Control.**" H. M. CHITTENDEN........Sept., "
Discussion........Nov., Dec., 1917, Jan., 1918

"**A Phenomenal Land Slide—Supplement.**" D. D. CLARKE........Sept., 1917
Discussion........Jan., 1918

"**Hydraulic Phenomena and the Effect of Spreading of Flood Water in the San Bernardino Basin, Southern California.**" A. L. SONDEREGGER....Sept., 1917
Discussion........Nov., "

"**The Subsidence of Muck and Peat Soils in Southern Louisiana and Florida.**" CHARLES W. OKEY........Sept., "
Discussion........Nov., Dec., 1917, Jan., 1918

"**Pulsations in Pipe Lines, as Shown by Some Recent Tests.**" H. C. VENSANO........Oct., 1917
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"**A Brief Review of Trigonometrical Mathematical Tables, and a Contemplation of the Specifications for Trigonometrical Tables for General Use.**" VIRGIL A. EBERLY........Oct., "
Discussion........Dec., 1917, Jan., 1918

"**The Hell Gate Arch Bridge and Approaches of the New York Connecting Railroad Over the East River in New York City.**" O. H. AMMANN....Oct., 1917
Discussion........Dec., 1917., Jan., 1918

"**Stress Measurements on the Hell Gate Arch Bridge.**" D. B. STEINMAN...Oct., 1917
Discussion........Dec., 1917, Jan., 1918

"**Construction Problems of the Manhattan-Bronx, and Lexington Avenue Subway Junction and Queensborough Tunnel Connections.**" GEORGE PERRINE........Nov., 1917
Discussion........Jan., 1918

Report of Joint Conference Committee on Specifications and Methods of Tests for Portland Cement........Nov., 1917

"**The Activities of the American Society of Civil Engineers During the Past Twenty-five Years.**" CHAS. WARREN HUNT........Dec., "

"**Ice Diversion, Hydraulic Models, and Hydraulic Similarity.**" BENJAMIN F. GROAT........Dec., "

"**Manhattan Elevated Railway Improvements.**" F. W. GARDINER and S. JOHANNESSON. (To be presented Feb. 6th, 1918.)........Dec., "

"**Final Report of the Special Committee on Materials for Road Construction, and on Standards for Their Test and Use**........Dec., "

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Progress Report of the Special Committee on the Regulation of Water Rights.Dec., "

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PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XLIV—No. 2

AMERICAN
SOCIETY OF
CIVIL
ENGINEERS
FOUNDED
1852

February, 1918

Published at the Headquarters of the Society, 33 West Thirty-ninth Street, New York,
the Fourth Wednesday of each Month, except June and July.

Copyrighted 1918, by the American Society of Civil Engineers.
Entered as Second-Class Matter at the New York City Post Office, December 15th, 1896.
Subscription, $8 per annum.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852)

VOL. XLIV—No. 2

FEBRUARY, 1918

Edited by the Secretary, under the direction of the Committee on Publications.

Reprints from this publication, which is copyrighted, may be made on condition that the full title of Paper, name of Author, page reference, and date of presentation to the Society, are given.

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American Society of Civil Engineers

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Special Committees

ON ENGINEERING EDUCATION: Desmond FitzGerald, Onward Bates, D. W. Mead.

TO CODIFY PRESENT PRACTICE ON THE BEARING VALUE OF SOILS FOR FOUNDATIONS, ETC.: Robert A. Cummings, Edwin Duryea, E. G. Haines, Allen Hazen, James C. Meem, Walter J. Douglas.

ON THE REGULATION OF WATER RIGHTS: F. H. Newell, W. C. Hoad, John H. Lewis.

TO REPORT ON STRESSES IN RAILROAD TRACK: A. N. Talbot, A. S. Baldwin, G. H. Bremner, John Brunner, W. J. Burton, Charles S. Churchill, W. C. Cushing, Robert W. Hunt, George W. Kittredge, Paul M. LaBach, C. G. E. Larsson, G. J. Ray, Albert F. Reichmann, H. R. Safford, F. E. Turneaure, J. E. Willoughby.

◆

The Reading Room of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

HEADQUARTERS OF THE SOCIETY—33 WEST THIRTY-NINTH STREET, NEW YORK.

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CABLE ADDRESS........................"Ceas, New York."

Vol. XLIV. FEBRUARY, 1918. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

This Society is not responsible for any statement made or opinion expressed in its publications.

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MINUTES OF MEETINGS
OF THE SOCIETY

SIXTY-FIFTH ANNUAL MEETING*

January 16th, 1918.—The meeting was called to order at 10 A. M., in the Auditorium of the Engineering Societies Building; President George H. Pegram in the chair; Chas. Warren Hunt, Secretary; and present, also, about 650 members.

The President announced that he had appointed Messrs. Robert Ridgway, Thurston C. Culyer, Frederick W. Gardiner, Alexander Haring, C. V. V. Powers, James F. Sanborn, and Silas H. Woodard as Tellers to canvass the Ballot for Officers for the ensuing year.

The President delivered the Annual Address.†

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* A full report of the Sixty-fifth Annual Meeting is printed on pages 110 to 142 of this number of *Proceedings*.

† See page 359 of Papers and Discussions.

The Annual Report of the Board of Direction, and the Annual Reports of the Secretary and of the Treasurer,* for the year ending December 31st, 1917, were presented and accepted.

The Secretary read the report of the Committee to Recommend the Award of Prizes,† and announced that the medals and prizes for the year ending July, 1917, had been awarded by the Board of Direction in conformity with that report, as follows:

The Norman Medal to Paper No. 1366, "Chemi-Hydrometry and Its Application to the Precise Testing of Hydro-Electric Generators", by Benjamin F. Groat, M. Am. Soc. C. E.

The J. James R. Croes Medal to Paper No. 1370, "The Effects of Straining Structural Steel and Wrought Iron", by Henry S. Prichard, M. Am. Soc. C. E.

The Thomas Fitch Rowland Prize to Paper No. 1359, "The Astoria Tunnel Under the East River for Gas Distribution in New York City", by John Vipond Davies, M. Am. Soc. C. E.

The James Laurie Prize to Paper No. 1354, "Pearl Harbor Dry Dock", by H. R. Stanford, M. Am. Soc. C. E.

The Collingwood Prize for Juniors to Paper No. 1362, "The Cherry Street Bridge, Toledo, Ohio", by Clement E. Chase, Jun. Am. Soc. C. E.

The Secretary presented the report of the Tellers appointed by the Board of Direction to canvass the final suggestions for members of the Nominating Committee, to represent certain districts, and the following were appointed to serve for two years:

Charles E. Trout..............	Representing	District	No.	1
Clarence Blakeslee.............	"	"	"	2
Robert Farnham...............	"	"	"	4
John H. Darling...............	"	"	"	7
Charles A. Morse.............	"	"	"	8
Charles E. Johnston...........	"	"	"	9
Joseph Jacobs.................	"	"	"	12

Desmond FitzGerald, Past-President, Am. Soc. C. E., Chairman of the Special Committee on Engineering Education, reported progress, and Professor C. R. Mann addressed the meeting on that subject.

Robert A. Cummings, M. Am. Soc. C. E., Chairman of the Special Committee to Codify Present Practice on the Bearing Value of Soils for Foundations, reported progress.

A. N. Talbot, M. Am. Soc. C. E., Chairman of the Special Committee to Report on Stresses in Railroad Track, presented a Progress Report of that Committee.‡

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* For these reports see pages 24 to 39 of *Proceedings* for January, 1918 (Vol. XLIV).

† See page 110.

‡ Printed on pages 55 to 247 of Papers and Discussions in *Proceedings* for January, 1918.

On motion, duly seconded, the report was received and ordered printed in *Proceedings* and *Transactions*, and the Committee continued.

George W. Tillson, M. Am. Soc. C. E., on behalf of W. W. Crosby, M. Am. Soc. C. E., Chairman of the Special Committee on Materials for Road Construction and Standards for Their Test and Use, presented the Final Report of that Committee.*

On motion, duly seconded, the report was accepted and the Committee discharged with thanks.

Lewis D. Rights, M. Am. Soc. C. E., Chairman of the Special Committee on Steel Columns and Struts, presented the Final Report of that Committee.†

On motion, duly seconded, the report was received, and the Committee was discharged with thanks; it being understood that discussions on any of the reports of Special Committees would be received and printed in *Proceedings* and that such discussions would be answered by members of those Committees if considered desirable.

The Secretary announced that he had received discussions on the Report of the Special Committee on Steel Columns and Struts from Messrs. Gustav Lindenthal and Henry S. Prichard.

On motion, duly seconded, it was ordered that these discussions be not read, but be published in *Proceedings*.

A Progress Report of the Special Committee on the Regulation of Water Rights‡ was received and accepted as printed.

In the matter of the proposed revision of the Constitution,§ Nelson P. Lewis, M. Am. Soc. C. E., addressed the meeting and offered the following resolutions:

Whereas, the proposed revision of the Constitution of the Society, while containing many desirable changes, includes provisions which would define more narrowly the experience required for eligibility to the grade of Member; would vest in the Board of Direction full control over procedure relating to discipline under by-laws which may be adopted by the said Board and changed at its pleasure; would confer upon an Executive Committee of six (6) all the powers of the Board when the said Board is not in session, with the sole requirement that the other members of the Board shall be advised of its action; and would effect changes which have recently been submitted to the membership and rejected by a decisive vote; and

Whereas, it appears that the opinion of the members of the Board of Direction was greatly divided as to some of the changes; and

Whereas, the sections of the present Constitution relative to amendments only permit changes "pertinent to the original amendment" or reference to a committee for further consideration, which committee must report at the next general meeting, after which the amendment must go to letter-ballot; therefore, be it

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* Printed on pages 2327 to 2408 of Papers and Discussions in *Proceedings* for December, 1917.

† Printed on pages 2409 to 2459 of Papers and Discussions in *Proceedings* for December, 1917.

‡ Printed on pages 2461 to 2464 of Papers and Discussions in *Proceedings* for December, 1917.

§ See *Proceedings* for May, 1917, p. 315

Resolved, that the proposed revision of the Constitution be ordered to letter-ballot with the statement that, in view of the objections above indicated, it is the sense of this meeting that it should not be adopted; and be it further

Resolved, that a copy of this preamble and resolution be sent to each corporate member with the form of ballot for voting upon the proposed revision.

These resolutions were seconded by Gardner S. Williams, M. Am. Soc. C. E., and adopted as the action of the meeting.

Robert Ridgway, M. Am. Soc. C. E., presented the report of the Tellers appointed to canvass the Ballot for Officers for the ensuing year.

The President announced the election of the following officers:

President, to serve one year:

ARTHUR N. TALBOT, Urbana, Ill.

Vice-Presidents, to serve two years:

JOHN F. COLEMAN, New Orleans, La.
NELSON P. LEWIS, New York City.

Treasurer, to serve one year:

GEORGE W. TILLSON, Brooklyn, N. Y.

Directors, to serve three years:

GEORGE W. GOETHALS, New York City.
ANDREW M. HUNT, New York City.
SAMUEL T. WAGNER, Philadelphia, Pa.
EDWARD E. WALL, St. Louis, Mo.
MILO S. KETCHUM, Boulder, Colo.
HARRY HAWGOOD, Los Angeles, Cal.

Desmond FitzGerald and Frederic P. Stearns, Past-Presidents, Am. Soc. C. E., conducted Mr. Talbot to the chair.

Mr. Talbot addressed the meeting briefly.

Adjourned.

February 6th, 1918.—The meeting was called to order at 8.30 P. M.; Vice-President George W. Kittredge in the chair; Chas. Warren Hunt, Secretary; and present, also, 127 members and 14 guests.

The minutes of the meetings of December 19th, 1917, and January 2d, 1918, were approved as printed in *Proceedings* for January, 1918.

A paper by F. W. Gardiner and S. Johannesson, Members, Am. Soc. C. E., entitled "Manhattan Elevated Railway Improvements", was presented by the authors and illustrated with lantern slides.

The paper was discussed by Messrs. T. Kennard Thomson, George H. Pegram, Edward Wegmann, H. Constable, C. E. Carpenter, and F. W. Gardiner.

The Secretary announced the following elections on January 14th, 1918:

As Members

Frank Harrison Bailey, Nenana, Alaska
Ossian Elmer Carr, Niagara Falls, N. Y.
Ralph Dominguez, Buenos Aires, Argentine Republic
John Thomas Keenan, Edgewood, R. I.
William Schurman Lea, Montreal, Que., Canada
Arthur Wood Neel, New York City
Lionel Rene Viterbo, St. Louis, Mo.
Ernest Hardwick Wilcox, Los Angeles, Cal.

As Associate Members

Alexander Alexander, Troy, N. Y.
Edward Taber Almy, Jr., Kansas City, Kans.
Roy Frederic Bessey, Washington, D. C.
Edwin Wallace Borough, Trenton Falls, N. Y.
Ralph Bosard, Memphis, Tenn.
Richard Ludwig Brandt, San Antonio, Tex.
Warren Henderson Buchanan, Gulfport, Miss.
John Schroder Carpenter, Springfield, Ohio
Arthur Grover Cleveland Chapman, Providence, R. I.
William Claney Edgar, Jersey City, N. J.
Glenn Perkins Edwards, Poughkeepsie, N. Y.
Laurence Emerson Frissell, New York City
Harry Parker Hammond, New York City
John McRae Hartgering, Detroit, Mich.
Marshall Howard, Council Bluffs, Iowa.
Theodore Human, Jr., Cayo Mambi, Oriente, Cuba
Emil Federic Jacobi, Bayonne, N. J.
Leslie Ingalls Johnstone, Winnipeg, Man., Canada
John Martin Kemmerer, Chicago, Ill.
Peter Magnus Larsen, Chicago, Ill.
Albert Mortimer McPherson, Milford, Utah
William Montgomery Mitchell, Flint, Mich.
John Edward Openshaw, Montreal, Que., Canada
Herbert Gregor Outwater, New York City
Rennick Rubenell Paine, Evanston, Wyo.
Benjamin Gilbert Pasco, Center, Miss.
Ashton Ramsay Peyton, Denver, Colo.
Earle Russell, Berkeley, Cal.

William Japha Schlick, Ames, Iowa
William Frank Stanton, Valparaiso, Chile
David Field Stockbridge, Oklahoma, Okla.
Gaither Hunter Sykes, Ellicott City, Md.
James Sykes, Denver, Colo.
Walter Charles Voss, Brookline, Mass.
Henry Lewis Wheeler, Auberry, Cal.
Frank Osmond White, New York City
Merton Horatio Willis, Tampico, Mexico
Maurice Mayer Wyckoff, Boston, Mass.

As Juniors

Edwin Leo Ball, Pineville, La.
Frederick Martin Cleckner, Erie, Pa.
Clinton Stowell Darling, South Vernon, Mass.
Enrique Diaz, Rugby, England
Percival Elliott, Roanoke, Va.
Albert Hartwell Jewell, Lansing, Mich.
Charles Raymond Larkin, Philadelphia, Pa.
Arthur Branch McGee, Pasadena, Cal.
John Owings Preston, Rochester, N. Y.

The Secretary announced the following transfers on January 14th, 1918:

From Associate Member to Member

Dudley Frank Black, Denver, Colo.
Clifton Ewing Hickok, Alameda, Cal.
George Henry Knutson, Jackson, Mich.
Walter Frederick Reichardt, Camp Beauregard, La.
Henri Rusch, St. Louis, Mo.
William Day Shannon, Youngstown, Ohio
Ezra Collin Shoecraft, Flint, Mich.
Russell Biddle Smith, New York City
Edward Smulski, New York City
Alfred Howe Terry, Fairfield, Conn.
Warren Bertram Travell, New York City
Needham Everett Waddell, Kansas City, Mo.
Frank Johnson Trelease, New Orleans, La.

From Junior to Associate Member

Clarence Reed Carter, Devine, Tex.
Ivan Charles Crawford, Greden, Colo.
Samuel Cellner Dreyfus, Columbia, S. C.
Lewis Alden Estes, Boston, Mass.

George Inness Gay, London, England
John Robert Haswell, Washington, D. C.
Roland Ellis Hutchins, Memphis, Tenn.
Frank Melvin S. Johnson, Vancouver, Wash.
William Bruce McMillan, San Jose, Cal.
Jared Leroy Mathias, Descanso, Cal.
Donald Curtis May, Ann Arbor, Mich.
John Owen Miller, San Francisco, Cal.
Louis Watters Payne, Chuquicamata, Chile
Ruble Isaac Poole, West Raleigh, N. C.
Alexander Crawford Smith, Jr., Baltimore, Md.

From Junior to Associate

Walter Ferrell Winton, Fort Sill, Okla.

The Secretary announced the following deaths:

William Bradford, of Pittsburgh, Pa., elected Member, December 7th, 1898; died November 23d, 1917.

Thomas Francis Curran, of Utica, N. Y., elected Associate Member, August 31st, 1915; died January 8th, 1918.

William Hague, of New York City, elected Associate Member, October 4th, 1910; died January 1st, 1918.

Jay Cassius Canney, of Gary, Ind., elected Junior, May 31st, 1916; died September 15th, 1917.

Adjourned.

REPORT IN FULL OF THE SIXTY-FIFTH ANNUAL MEETING, JANUARY 16TH AND 17TH, 1918.

Wednesday, January 16th, 1918 (10 A. M.).—The Sixty-fifth Annual Meeting was called to order in the Auditorium of the Engineering Societies Building, 39 West 39th Street, New York City; President George H. Pegram in the chair; Chas. Warren Hunt, Secretary; and present, also, about 650 members.

THE PRESIDENT.—The meeting will please come to order. I shall appoint as Tellers, to canvass the Ballots for Officers, Messrs. Robert Ridgway, Thurston C. Culyer, Frederick W. Gardiner, Alexander Haring, C. V. V. Powers, James F. Sanborn, and Silas H. Woodard.

The first order of business, I believe, is the President's Annual Address.

(The President delivered the Annual Address.*)

THE PRESIDENT.—The next business is the report of the Board of Direction, which the Secretary will please read.

The Secretary presented the report of the Board of Direction.†

In reading that part of the Annual Report relating to the Roll of Honor, which in the *Proceedings* for November, 1917, contained the names of 575 officers, in the December *Proceedings*, 743 names, and 929 names on December 31st, 1917, the Secretary called attention to the Service Flag, hanging in the Auditorium, and containing 953 stars, and stated that at the present time the number would be nearly 1 000.

THE PRESIDENT.—That completes the report of the Board of Direction. If there is no objection it will be adopted as read. The report of the Secretary to the Board of Direction.

The Secretary read his report.‡

With this report there is a balance sheet, certified by a firm of public accountants, which I hardly think need be read.

The Secretary read the Treasurer's report.§

THE PRESIDENT.—If there is no objection, these reports will be accepted as printed.

Mr. Secretary, have you the Report of the Committee to Recommend the Award of Prizes?

THE SECRETARY.—Yes, sir; I have that report. It is as follows:

"DECEMBER 24, 1917.

"THE BOARD OF DIRECTION,
American Society of Civil Engineers,
33 West 39th St., New York City.

"GENTLEMEN: Your committee, appointed to 'Recommend the Award of Medals and Prizes for this year,' submits herewith the result of its scrutiny of papers and its more recent discussion of their merits, resulting in the following recommendations of awards:

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* See p. 359 of Papers and Discussions.

† See *Proceedings*, Am. Soc. C. E., Vol. XLIV, p. 24 (January, 1918).

‡ See *Proceedings*, Am. Soc. C. E., Vol. XLIV, p. 36 (January, 1918).

§ See *Proceedings*, Am. Soc. C. E., Vol. XLIV, p. 39 (January, 1918).

"1. The Norman Medal to Mr. Benjamin F. Groat for his paper (1366) entitled 'Chemi-Hydrometry and its Application to the Precise Testing of Hydro-Electric Generators.'

"2. The J. James R. Croes Medal to Mr. Henry S. Prichard for his paper (1370) entitled 'The Effects of Straining Structural Steel and Wrought Iron.'

"3. The Thomas Fitch Rowland Prize to Mr. John Vipond Davies for his paper (1359) entitled 'The Astoria Tunnel under the East River for Gas Distribution in New York City.'

"4. The James Laurie Prize to Mr. H. R. Stanford for his paper (1354) entitled 'Pearl Harbor Dry Dock.'

"5. The Collingwood Prize for Juniors to Mr. Clement E. Chase for his paper (1362) entitled 'The Cherry Street Bridge, Toledo, Ohio.'

"Respectfully submitted,

"H. J. BURT,
S. EVERETT TINKHAM,
J. L. VAN ORNUM, *Chairman.*"

THE SECRETARY.—Mr. President, I have to report that this report of the Committee was received by the Board of Direction, and its recommendations as to the award of prizes unanimously adopted.

THE PRESIDENT.—The next order of business is the report of the Board on account of the final suggestions received from the various Districts. Have you that report?

THE SECRETARY.—Yes, sir.

The Secretary presented the report of the Tellers, as follows:

"TO THE BOARD OF DIRECTION:

"The undersigned tellers report the result of canvass of final suggestions for Members of the Nominating Committee in the several districts as follows:

"District No. 1.—	Charles E. Trout	156
	J. S. Langthorn	63
	B. F. Cresson, Jr.	25
	Scattering	13
	Total	257

"District No. 2.—	Clarence Blakeslee	100
	C. M. Spofford	26
	Charles R. Gow	16
	Scattering	3
	Total	145

“*District No. 4.*—	Robert Farnham	38
	John F. Murray	18
	C. J. Tilden	12
	Scattering	18
	Total	86
“*District No. 7.*—	J. H. Darling	51
	H. E. Riggs	31
	William G. Raymond	15
	Scattering	6
	Total	103
“*District No. 8.*—	C. A. Morse	109
	Richard Montfort	8
	W. H. Finley	4
	Scattering	6
	Total	123
“*District No. 9.*—	C. E. Johnston	121
	Baxter L. Brown	41
	Scattering	6
	Total	168
“*District No. 12.*—	Joseph Jacobs	19
	D. C. Henny	14
	E. B. Hussey	10
	Scattering	5
	Total	48

“Respectfully submitted,

“F. C. Noble,
Lewis D. Rights,
Alfred D. Flinn.”

The Districts were taken up separately, and by vote of the meeting, the following members of the Nominating Committee were appointed to serve for two years:

Charles E. Trout	*Representing District No.*	*1*
Clarence Blakeslee	“ “ “	*2*
Robert Farnham	“ “ “	*4*
J. H. Darling	“ “ “	*7*
C. A. Morse	“ “ “	*8*
C. E. Johnston	“ “ “	*9*
Joseph Jacobs	“ “ “	*12*

THE SECRETARY.—Mr. President, will you then declare that Messrs. Charles E. Trout, Clarence Blakeslee, Robert Farnham, J. H. Darling, C. A. Morse, C. E. Johnston, and Joseph Jacobs are appointed members from the several Districts to the Nominating Committee?

THE PRESIDENT.—I declare the men whose names have been read appointed as members of the Nominating Committee.

I call for the report of the Special Committee on Engineering Education; Mr. FitzGerald:

DESMOND FITZGERALD, PAST-PRESIDENT, AM. SOC. C. E.—Mr. President, it has been a good many years that your Committee has been working on this subject, but it gives me great pleasure to say that our work is now nearing completion. I propose to read a short report now, in the way of a progress report, and probably the permanent report of the Committee—the final report—will be made before the end of the year, transmitting a very important document to this Society from the Carnegie Foundation.

Your Committee would much rather be found on the side of those who admire the spirit and work of the schools than on the side of those who are constantly endeavoring to magnify their shortcomings.

Especially is this true in this great time of emergency, with the greatest war of history on our hands, and we, ourselves, at an average distance of about 5 000 miles from the battle-fields.

We must all appreciate the work in aid of the war, which the technical schools have suddenly been called on to accomplish, and the magnificent way in which they have responded. They have given up their time and energies to every problem with zeal and intelligence, and with no other aim than a desire to develop all their great resources of training and equipment for the service of the country. Even those in closest touch with their work know only a fraction of their efficiency, but they know that, if we ever succeed in maintaining a great army and navy on the other side of the wide ocean which separates us from Europe, it will be because trained graduates from the schools, and the schools themselves, have linked arms with the practical men of affairs in order to win this war.

Though a thankless task, we must turn our eyes to such matters as lack of co-ordination among instructors, confusion of curricula, and unbalanced methods of instruction; and these are exactly the problems which your Committee has been studying during the past nine years. Now, at last, a ray of light breaks across our work, and we are glad to report that there is the strongest promise that before the summer is here we shall have the pleasure of transmitting to the Society the report of the Carnegie Foundation and of Dr. Mann, its expert, which we have been long anticipating.

Last year I stated that the report was ready for the printer. Further study made it apparent that the report would be of greater value to engineers if it were simplified and condensed. This great work has been done, and Dr. Mann's report has been reduced from 175 pages to but 75, and in a few days it will be in the hands of the printer. Dr. Mann is present to-day, and will say a few words to you on this matter.

I wish to say here that I think the appreciation of this Society is due to the Carnegie Foundation, to Dr. Pritchard and to Dr. Mann, for the admirable way in which they have responded to every desire of the Committee to examine this subject with the greatest possible care; and they have devoted long years and very large sums of money, without a cent of expense to this Society, to the accomplishment of this result.

Dr. Mann is here, and, with your permission, Mr. President, I am going to ask him to say just a few words to you on this subject, because the work is now nearing the end.

THE PRESIDENT.—We shall be pleased to hear from Dr. Mann.

C. R. MANN, ESQ.—Mr. President and Gentlemen, two years ago the answers to the questionnaire that was being conducted under the auspices of your Committee and the committees of the other National Societies showed that we had progressed to a point where we had discovered that contracting engineers, when asked the question: What qualities in young men do you look for and regard as most important in selecting men for particular jobs? had mentioned personal qualities, such as character, personality, initiative, and so on, seven times as often as they had mentioned knowledge of technical science. That was the report two years ago.

Last year, and a year ago, the report indicated that the analysis of the problem had been carried to a point where we saw that this emphasis on personal qualities required a type of education which should motivate the student, and which would correlate and interrelate the subjects in such a way that the student would see or learn to connect things that ought to be connected, and would do it with enthusiasm.

Now, that solution, or that stage of the problem, was not satisfactory, either to the Committee or to the schools, because we all know (who are in school work) that interrelation and motivation have been the problems of education for a great many years, and that motivation, particularly, is open to the criticism that it leads to "sugar-coating the pill", and, "let Johnnie do what he likes", and things of that sort, which is not at all what we want in engineering education.

During the past year, because of the great crisis which had come upon the Government, and because of the enormous amount of attention that had been given to this subject by the engineers themselves, we have been enabled to push the analysis of the problem one step further. I think this time we have pushed it to hardpan, and discovered a foundation on which we can safely build. This comes from the analysis of the engineering problem. I think you will all agree that every engineering problem contains three essential elements, namely: science, practice, and cost; and, in its solution, these three elements have to be carefully considered.

I think you will all agree that the schools deal with the science with a fair degree—a large degree—of satisfaction. They deal to a less degree with the question of practice, that is, seeing that the science is so adapted to the practical conditions of manufacturing that the thing can actually be constructed; but, with the question of costs, the schools at present deal very, very little. There are a few of them that ask the boys to prepare bills of materials, and there are one or two places where the boys are resolved into a group of contractors for a short time to make a bid on some engineering structure.

Now, the entire control of engineering in this country rests in the hands of those who determine whether the value received, or the value that accrues from an engineering structure, is worth the cost; and that phase of the question is not dealt with at all in the engineering schools; and, therefore, we have analyzed the engineering curriculum to see what features have to be changed or what features added in order to introduce a training in the appraisement of values and costs in engineering work into the work of the schools, that is, an appraisement of the value of costs, which we believe to be the controlling and the essential factor, the most important factor, in the practical work, but it is a factor that is not receiving any attention whatever in the schools.

I may say that the organization of the report, as it has been appraisement of values and costs means, in applying entrance require- appraisement of values and costs means, in applying entrance requirements, in organizing the curriculum, the marks in grading, in organizing the faculty, and in the technical details of school work.

It is, of course, impossible to go into details here. I hope the report will be in your hands in a few weeks now, so that you can study the solution.

There is one other point that I want to present to this Society this morning. The engineering schools, as Mr. FitzGerald has said, have responded patriotically and loyally to the demands of the Government for training engineers and for maintaining engineering training during the war.

Because of the assistance which we received from this Society and from the other Founder Societies, it was possible to make arrangements with the War Department, whereby students in engineering, whom the schools are willing to certify as probably and likely to become valuable engineers, may remain in school and finish their training before taking up active service.

The development in the war preparations has now reached a stage where the various divisions of the Army, the Navy, and the Shipping Board are beginning to be able to tell the schools what particular types of training they need to have carried out. A committee has been working in Washington for the last six weeks, endeavoring to tell the schools, or find out for the schools, what types of training they can profitably take up for war work.

We have been unable, until very recently, to find out from the Government, or from the various branches of the Government, what types of training they need. That is the first question. Now, those needs are beginning to be apparent; for instance, two weeks ago the Signal Corps announced that they needed 500 radio engineers. There is a specific need which the schools can take up.

Now, the difficulty of meeting that need is that there is no organization, and no board, no bureau, no office in Washington, that is charged with the function of co-ordinating those needs for training for war purposes and the educational institutions; and the latter are at present in a state of great chaos. They are very eager to serve, but they do not know what to do, and there is no agency for correlating the demand for engineering training and the needs for supplying that training.

The committee that has been working on this has been endeavoring for a number of months to have such an agency established. I may say that this Society is directly interested in that, because, as I have followed the attempts of the various societies to be of service, it has seemed to me that they were having great difficulty in finding out from Washington what was needed.

There is a great need of some agency that will determine what engineering talent and ability is needed, and where it is needed, and then go to work and supply it. Now, I would like to suggest that this Society can be of service in helping the engineering schools into order, and into a helpful, useful relation to the Government, if they would bring such pressure as they can to bear upon the authorities at Washington to establish a co-ordinating agency for engineering interests there. Because, if we had a central office where all demands for engineering training were accruing and placed in order, if there were there men from the schools, who understand the schools and know what they can produce, to distribute those things into the proper channels in the schools, the efficiency of the entire machine would be enormously increased.

Therefore, I suggest—as a thing that this Society can do—the bringing of pressure to bear upon the officials in Washington to establish such an engineering agency. You have doubtless noticed that in the last two weeks there has been established such a central agency for the general situation of technical labor. They have established in the Department of Labor a bureau for studying labor conditions and a bureau for employing labor to meet just the needs of the Government.

So far, the engineers are classed under that head, and the only agencies that I have been able to discover there to deal with the engineering question are those two bureaus.

Now, I rather think that those are good bureaus to connect up with, so that one office would deal with the whole question of technical service from the top to the bottom; but, at any rate, there is need of some centralizing authority in Washington to deal with this engineering problem; and I urge it upon your attention and hope that this meeting may take action in the matter. I thank you.

GARDNER S. WILLIAMS, M. AM. SOC. C. E.—Mr. President, allow me to say a word in reply to the report of the Committee. In 1905 I had the honor of establishing in the University of Michigan a course in which instruction upon the line of costs was given, and about 10% of the time of the senior class was devoted to that phase of the subject.

The matter was taken up the year following by the Department of Mechanical Engineering, and, to the best of my knowledge and belief, is still continued there. I think the Committee is somewhat behind the times.

DR. MANN.—You will recall that I said that some schools had introduced work of that sort, and it happens that the University of Michigan is one of them, because the course I mentioned a minute ago—to organize the class into a group of contractors who would bid on a certain engineering construction—is carried out at that University.

THE PRESIDENT.—If there are no further remarks, the Committee's report will be accepted.

The report of the Special Committee to Codify Present Practice on the Bearing Value of Soils for Foundations, etc.: Mr. Robert A. Cummings, Chairman. Is Mr. Cummings present?

Mr. Cummings presented his report, as follows:

"JAN. 16TH, 1918.

"TO THE AMERICAN SOCIETY OF CIVIL ENGINEERS:

"Your Special Committee appointed to Codify Present Practice and Report on the Physics of Soils, in relation to Engineering Structures, respectfully submits this interim report.

"During the past year your Committee held three meetings, and the Minutes have been published in the monthly *Proceedings* of the Society.

"The discussion of the last Report of your Committee has been carefully studied with appreciation and interest.

"Your Committee has continued the study of proposed definitions and classification of soils, but the results are yet incomplete.

"The labors of your Committee on granulometric analysis, sizing, grading, and charting, have met with much encouragement in a development of simple methods. These will be tested out and reported later.

"Your Committee has continued the study of published articles and data, and has in progress a descriptive classification of the manner in which soils give trouble.

"Your Committee has in preparation proposed uniform methods and devices for the practical testing of soils of foundations.

"These and other activities of your Committee, as of all similar investigations, are now very much restricted by the Great War. As individual units, your Committee members are devoting themselves to the service of the United States wherever possible, and your Committee is acting upon the suggestion made by your Board of Direction to subordinate its work to the National interests. For similar reasons, the Sub-committee of the United States Bureau of Standards, which is co-operating with your Committee in the scientific aspect of its problems, is unable to present a report at this time.

"Respectfully submitted in behalf of the Committee,

"Robert A. Cummings,
"*Chairman.*"

Committee:
Walter J. Douglas, *Secretary*
Edwin Duryea
E. G. Haines
Allen Hazen
J. C. Meem
Robert A. Cummings, *Chairman.*

The President.—Is there any discussion on this report? If not, the report will be received.

The Report of the Special Committee to Report on Stresses in Railroad Track: Professor A. N. Talbot, Chairman. Is Professor Talbot present?

A. N. Talbot, M. Am. Soc. C. E.—The Special Committee on Stresses in Railroad Track presents a Progress Report which has been printed* and distributed. Since this report was completed the Committee has continued its labors, and has done work on the distribution of pressures through ballast, on the effect of counterweight and excess counterweight in the locomotive, on the rail, and on the effect of curves. Mr. President, I move that this report be accepted as a report of progress, and that it be printed in the *Proceedings* and in the *Transactions.*

(Motion duly seconded.)

The President.—All in favor of that motion will say "aye"; those opposed, "no". The motion is carried.

The Final Report of the Special Committee on Materials for Road Construction, and on Standards for Their Test and Use: W. W. Crosby, Chairman. Is Mr. Crosby here?

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* *Proceedings,* Am. Soc. C. E., January, 1918. Papers and Discussions, p. 55.

The Secretary.—No; but Mr. Tillson is.

The President.—Will Mr. Tillson make the report for Mr. Crosby?

George W. Tillson, M. Am. Soc. C. E.—Mr. President and Gentlemen: On account of the absence of the Chairman of this Committee, Col. Crosby, who is in the service of the United States, it has devolved upon me to present this report.

The report has at least one merit: It is final. During the last few years, when this Committee has presented its Progress Reports, it has held, subsequent to the Annual Meeting, meetings for informal discussions on the report, in order to get the ideas of other members of the Society interested in the subject, and also of men who were not members of the Society.

These meetings have been well attended, and the discussions have been full. The Committee has considered very carefully all the ideas introduced at those discussions, but has not been able to agree to. or to insert in the report, everything that has been presented, because, for one reason, in very many cases absolutely opposite ideas were expressed.

The Committee, therefore, does not expect that the report will suit every one. Possibly, or perhaps probably, it would not suit in every particular every member of the Committee itself. It is, however, a composite view of the members of the Committee. The Committee, too, wants to present again the idea, which I mentioned a year ago in presenting the Progress Report, and that is that a report of this kind on a subject which is, you might say, in an experimental stage even now, even if it were absolutely up to date at this time, could not be expected to be up to date one year from now; and, in order that this Society, or any society, may keep a subject like this up to date, it would require constant care, constant study, and an Annual Report, although this Committee does not recommend that.

The Committee, therefore, submits this report to the Society as its final action; and I want to move, Mr. President, the acceptance of the report and the discharge of the Committee from further consideration of the subject.

(Motion duly seconded.)

Clemens Herschel, Past-President, Am. Soc. C. E.—I would like to add to the motion the thanks of the Society to this Committee.

The President.—The thanks of the Society will be added to the motion. Gentlemen, you have heard the motion. All in favor of accepting the report of the Special Committee on Materials for Road Construction, with the discharge of the Committee and the expression of the thanks of the Society to the Committee, will say "aye"; those opposed, "no". The motion is carried.

The Final Report of the Special Committee on Steel Columns and Struts: Mr. Lewis D. Rights, Chairman. Is Mr. Rights present?

Lewis D. Rights, M. Am. Soc. C. E.—Mr. President and Gentlemen: The report of the Special Committee on Steel Columns and Struts is also a Final Report. It was printed in the December *Proceedings*, so that by this time probably all the members have had a chance to look at it. The first pages, up to page 2432, give a history of the work of the Committee and republish material which was given in the Progress Reports of 1915, 1916, and 1917.

The gist of the report, probably, or the critical point, is on page 2444. The Committee discovered that heavy columns fell off in unit strength. This was investigated, and was found to be due to the material. The Committee looked for some critical point which would give the correct indication of the strength of the material, and was not able to discover any former definitions, so, after considerable deliberation, it adopted a new term. This was not done hastily.

"The Committee has defined the critical point"—I am reading from the report—"as the point which is determined graphically by drawing a line tangent to the envelope of the stress-strain curve, having a slope of one-half that of the last run-up line for its straight, or nearly straight, portion."

You will see by the diagram on page 2444 (Fig. 7) an illustration of this method of determining the critical point. To say it another way, you will notice that the modulus of elasticity shown for this particular diagram is 28 000 000, which is the point where the modulus of elasticity becomes half of that or 14 000 000. Possibly, in another way, it may be said to be the point where the rate of deformation becomes twice what it is somewhere near the origin of the stress-strain point.

The Committee adopted this method of determining the critical point, both for specimen tests and for the full-sized columns in Table 22, which shows the relation between the ultimate strength, as determined both by the tests and by the Bureau of Standards, the yield points, and the new term, the "Useful Limit Points", and shows, as far as the Committee can see, that this new term, the "Useful Limit Point", bears a very distinct and constant relation to the full-sized strength of columns.

I might say a word right here in regard to the publication of diagrams. The Committee has a large number of diagrams and tables, tests, and logs, and it was thought at first that these should be published in full, so as to give the membership the benefit of all the work which had been done, but when the matter was investigated, it was found that the cost of publishing all these logs, diagrams, and other information would probably amount to more than the total cost of the Society's publications for this year. Naturally, it was prohibitive; so that the Committee has given only a few diagrams as samples.

The curves of Useful Limit Points and Safe Working Values are shown at the end of the report on Plate LXI. That shows the strength as indicated by the Useful Limit Points, and it shows a suggested curve, or—it is not a curve—the working values recommended by the Committee.

Now, in regard to the question of a rational column formula, the Committee in its report speaks of the desire of engineers for such a formula. I quote from the report, page 2456:

> "Numerous theoretical formulas have been promulgated from time to time, all of them based on entirely elastic material of uniform grade. At the present time it seems useless to the Committee to attempt to write a rational column formula, from a theoretical standpoint, with the possibility of variations of 28% in the strength of the material."

The Committee desires at this time to give public expression and thanks to the work done by the Bureau of Standards. Dr. Stratton, the Director, and his assistants have given the Committee every consideration. They followed out the suggestions made by the Committee, and all the work on tests has been done without expense to the Society; I am sure, therefore, that the Committee and the Society are grateful to the Director and his assistants for the work they have done.

Now, the only other matter to report is the suggestion of the Committee that it be discharged. This work is done, as far as it can go at the present time. The Bureau of Standards cannot continue making tests, because it is busy with war work, and the result is that the work will have to wait until after the war.

The Committee believes that it should make a final report and be discharged, and that, later, possibly when the war is over, if there is a demand for it, a new committee can better take up the work which has been carried on by this present Committee.

J. V. Davies, M. Am. Soc. C. E.—In seconding the motion of Mr. Rights for the discharge of the Committee, I would like to state that, in discharging the Committee with the thanks of this Meeting, it should be done with reference to the Board of Direction, so that the date of the termination of this Committee can take place at the option of the Board of Direction, when the answers have been received and criticisms of the report made, so as to enable the Committee to reply to any such criticisms.

C. E. Fowler, M. Am. Soc. C. E.—I would like to amend that by requesting the appointment of a new Committee, if this Committee is going to be discharged, because the time between now and the end of the war, which may be three years from now, can be profitably spent in planning the new campaign; and this Committee has only gotten to the border of the promised land, so far as bridge engineers are concerned.

It seems to me that it would be a decided catastrophe to drop a committee of this sort entirely out of sight for the duration of the war; and if the mover will accept that suggestion that a new committee be appointed, I would be glad——

The President.—The formula for appointing a new special committee is quite elaborate. It would take considerable time. It seems to me that the wishes of the members of the Committee should be regarded, and they have requested to be discharged. Perhaps Mr. Davies' suggestion might be met by what I believe is the custom, that the members of Special Committees in presenting their final reports should take sufficient interest in such reports properly to reply to ensuing discussions and criticisms; in fact, we could not consider it a final report until that were done.

Mr. Davies, will you agree to that understanding of the matter?

Mr. Davies.—Yes, sir.

Mr. Fowler.—In which case, I would like this Meeting to vote down the discharge of the Committee. If any members want to resign, and other members be appointed, that can be easily done. I do not think the Committee ought to be discharged if it is going to take a long while to appoint another one.

The Secretary.—Mr. President, in this connection I would like to read the last clause of Article VI of the Constitution:

> "Whenever, in the judgment of the Board of Direction, a special committee, appointed in the above prescribed manner, by reason of the long time required for its appointment, would be defeated in its object and be of no avail, then the Board of Direction shall be authorized to appoint forthwith a special committee to act in each case and report on each subject * * *."

In other words, it is within the power of the Board of Direction at any time to appoint such a committee, if the Board feels that it is necessary. I thought, perhaps, that might help the matter out a little.

The President.—Are there any other remarks? If not, you will vote on the motion to accept the final report of the Committee on Steel Columns and Struts, and discharge the Committee with the thanks of the Society. All in favor of the motion will say "aye"; opposed "no". The motion is carried.

The Secretary.—Pardon me. I have two written communications, one from Mr. Gustav Lindenthal and one from Mr. Henry S. Prichard. They have asked me to present these discussions on this report to the Meeting. It is for the Meeting to say whether they will hear them, or whether they will order them printed.

Leonard Metcalf, M. Am. Soc. C. E.—I move that the discussions be received without being read.

(Motion duly seconded.)

The President.—All in favor of the motion that the discussions be received and read by title only will say "aye"; opposed, "no". The motion is carried.

The Progress Report of the Special Committee on the Regulation of Water Rights: F. H. Newell, Chairman. Is Mr. Newell present?

The Secretary.—That report was printed in the December, 1917, *Proceedings*, and the gist of it was that it requested that the Committee be continued.

The President.—If there is no objection, that will be assumed.

The proposed revision of the Constitution:

Nelson P. Lewis, M. Am. Soc. C. E.—Mr. President, I presume discussion is in order, as this is a regular order of business?

The President.—Yes, sir.

Mr. Lewis.—Mr. President and Members of the Society, we have presented to us for our consideration to-day a complete revision of the Constitution of the Society. It contains many decided improvements over the present instrument by which the Society is governed. I think, however, that it also contains a number of rather serious objections. The time is, of course, very brief at this Meeting for a careful consideration of those objections.

Many of the amendments relate entirely to form. Their purpose has undoubtedly been to secure a somewhat more logical arrangement; in some cases, perhaps, better literary form. In many cases these efforts have been successful. Some of the changes are so slight that they might almost be called trivial; for instance, in Article I, Section 2, it is proposed to have that read: "The office of the Society shall be in the City of New York" instead of "shall be located in the City of New York."

In Article II, Section 1, "The Corporate Members shall be designated as Members and Associate Members," instead of, "The Corporate Members of this Society shall be designated as Members and Associate Members."

A little later "Graduation from a school of engineering of high standing" is proposed instead of "Graduation from a school of engineering of recognized reputation."

In one more instance, "Honorary Members shall be persons of eminence" is proposed, instead of as it now reads, "Honorary Members shall be chosen only from persons of acknowledged eminence."

These are specimens that run all through the proposed changes to the Constitution.

If I may briefly summarize the more important articles proposed: in Article I the changes are chiefly as to form. It includes a provision relative to subsidiary associations. This includes a plan already in force, and is a very excellent one. It provides that these associations shall be authorized by the Board of Direction, and shall conduct their business under by-laws from the Board of Direction.

In Article II, the age of Juniors is raised two years.

A Member "shall have had responsible charge of the construction of engineering work of high grade" instead of "responsible charge of work" as at present. The purpose, I think, is evident, and many of us would be in sympathy with it; but it does seem an unfortunate and needlessly narrow definition of engineering. It would apparently exclude men who have not had the required number of years "of responsible charge of the construction of engineering work of high grade," but who might have done splendid work for the Profession in research investigations; and I think it not unlikely that there are members of the Society of whom we are all proud to-day, who, if they were to be measured by that standard, might not be found eligible.

It is provided that Associates are hereafter to be known as Affiliates. Probably the purpose of this was to make a sharp distinction between Associates and Associate Members, Associate Members being Corporate Members, and there having been some misconception, I think, as between the relative rating of Associate Members and Associates.

Affiliates shall be persons of distinction. That may be rather a hard specification to define.

Article III. Matters of discipline, as well as admissions, are left entirely to the Board of Direction, to be conducted under by-laws to be adopted by the Board of Direction. There are no such by-laws now, and the Board shall adopt and may amend at pleasure these by-laws.

The principle is undoubtedly correct. The present machinery for disciplining members is cumbersome and wholly unsatisfactory; but there seems to be very grave objection to the entire omission from the Constitution of any constitutional guaranty to any Member of the Society, who may be subject to charges, which will ensure him even a hearing, and which will specify the vote of the Board of Direction by which the extreme penalty of expulsion may be imposed.

By-laws were suggested in the report of the Committee, by the Board of Direction, when this revision of the Constitution was suggested, but they are in embryo—no, not even in embryo—they may never be born, and they may be changed at will.

Now, undoubtedly, it may be said that this thing should be left to the Board of Direction. It should; and yet, we have confidence in our Board of Direction, I think. We nominate and elect them, and yet I doubt if the Board of Direction, which we elect and in which we have that confidence, would want to have this entire and absolute control over disciplinary measures, without the slightest suggestion of the constitutional protection of a man under charges, not even that he may be heard; and, as the Constitution or the proposed by-law is worded, it would appear that even the letter-ballot by the Board of Direction—that 20 affirmative ballots—might be required in a minor matter of discipline, such as a reprimand or a warning.

It seems to me that this objection is fundamental, and the organic law should insure that protection to any Member.

In Article IV the changes are mostly in form. The Board is left to deal with those in arrears for dues under by-laws which it may adopt.

Exemption from dues now granted to Members of the Society, when they have reached the age of 70 years and have paid dues for 25 years, is omitted, and Corporate Members and Affiliates must have paid dues for 35 years in order to reach the age of exemption. That perhaps is unobjectionable, and yet it seems a little needlessly severe; but it should be noted that there is a possible lack of protection for Affiliates, as Corporate Members and Affiliates must have paid dues as such for 35 years before they are exempt. The new Affiliates cannot have paid as Affiliates for 35 years.

The intent of the Constitution is undoubtedly to insure to any Member, in any grade at present, whatever rights he may have, and it may be hypercritical to point out that possible lack of protection for Affiliates; and yet it is there.

In Article VI there are several important changes. The Board is to adopt by-laws and to amend them at will, apparently, at any meeting, without previous notice. It is only required that they advise the Members of the Society of the by-laws which they adopt, and of the changes which they may make; and yet this Board is to deal with matters affecting the rights and status of any member of the Society under by-laws as meager and as fragile as these.

It provides, also, for an Executive Committee, which shall possess all the powers of the Board of Direction when that Board is not in session. The members of that Committee, apparently, so far as we know and see, could amend by-laws, could take action prejudicial to the interests of the Society and the rights of Members, and such action would be legal.

Now, you may say that this is very unlikely. It is unlikely; but, gentlemen, it should be impossible. The organic law of this great Society of more than 8 000 members should certainly make it impossible for any Board of Direction, no matter what confidence we have in it, to do a thing of that kind, however unlikely it is that they would attempt to do it. It seems to me a very fundamental and fatal defect.

It also omits the provision that the Secretary shall be elected annually by the Board of Direction at the meeting to be held within 20 days after the Annual Meeting. The time for the election is not specified. I know it appears from the report that there has been some discussion as to having this election before the Annual Meeting. That seems to be unwise, that an outgoing Board should elect the Secretary to serve the incoming Board.

By Article VII the Nominating Committee is to be elected as prescribed by the Board through its by-laws—by-laws which may be changed at any meeting, or possibly by the Executive Committee.

Nominees are to be elected only from Corporate Members resident in their Districts. Now, this is probably in the interest of representative government, and I think it probable that it is a wise provision. There is, of course, the possibility that Members so elected would regard their duty to their constituents in their particular Districts as paramount to their duty to the Society; but I think that danger is negligible.

In Article VIII the changes are simply a rearrangement and modification of the material, the only important change being that a quorum at a meeting of the Board at the time of the Annual Meeting should be 15 instead of 9, while at other meetings it remains at 5.

It is perhaps a little difficult to understand why this particular meeting of the Board—the briefest meeting and perhaps in many respects the most important of the year—should require an increase in the members in attendance to create a quorum.

Article IX is intended to simplify proposed amendments. They must be referred to the Board of Direction. That Board, however, is limited in its action to approval or revision as to form and validity only.

I cannot but believe that the Board of Direction can give more patient and careful deliberation to these amendments, and deal with the substance as well as the form in a much more satisfactory fashion than this meeting is at present able to do at a quarter past 12, when the meeting must adjourn at 1 o'clock.

In referring to one of the sections, gentlemen, I think I omitted to refer to the proposed change excluding the Secretary from the Board. This was presented to the membership 3 years ago, in 1914, and not only failed to receive the necessary two-thirds' vote, but received only 42% of the total vote cast.

Now, this revision is before us. What are we to do with it? I think it deplorable that the proposition of the adoption of an instrument, which has had so much time spent upon it and contains so many excellent changes, should have been jeopardized by the inclusion of some of the objectionable features, and I certainly think them objectionable—those which I have pointed out—and in view of this situation, Mr. Chairman and gentlemen, I offer this resolution:

"*Whereas*, the proposed revision of the Constitution of the Society, while containing many desirable changes, includes provisions which would define more narrowly the experience required for eligibility to the grade of member; would vest in the Board of Direction full control over procedure relating to discipline under by-laws which may be adopted by the said Board and changed at its pleasure; would confer upon an Executive Committee of six (6) all the powers of the Board when the said Board is not in session, with the sole requirement that the other members of the Board shall be advised of its action, and would effect changes which have recently been submitted to the membership and rejected by a decisive vote; and

"*Whereas*, it appears that the opinion of the members of the Board of Direction was greatly divided as to some of the changes; and

"*Whereas*, the sections of the present Constitution relative to amendments only permit changes 'pertinent to the original amendment' or reference to a committee for further consideration, which committee must report at the next general meeting,' after which the amendment must go to letter ballot; therefore, be it

"*Resolved*, that the proposed revision of the Constitution be ordered to letter ballot with the statement that, in view of the objections above indicated, it is the sense of this meeting that it should not be adopted; and be it further

"*Resolved*, that a copy of this preamble and resolution be sent to each corporate member with the form of ballot for voting upon the proposed revision."

I offer that resolution, Mr. President.

MR. WILLIAMS.—I support the resolution, Mr. President.

THE PRESIDENT.—You have heard the resolution, and it is now before you for discussion.

Apparently, no one desires to speak. All in favor of the resolution will say "aye"; opposed, "no". It is carried.

Announcements by the Secretary.

THE SECRETARY.—Mr. President, everybody here has a copy of the programme, in detail, of the Meeting; and I do not think that I need go into that at all.

I would like to read, however, the following communication from Headquarters, Seventy-seventh Division, Camp Upton, New York:

"HEADQUARTERS 77TH DIVISION,
"CAMP UPTON, N. Y., JANUARY 14TH, 1918.

"MEMORANDUM:

"1. The members of the American Society of Civil Engineers attending their annual meeting in New York City, January 16th and 17th, will visit Camp Upton on the 17th by special train arriving at 11:45 A. M., and leaving for New York at 3:30 P. M.

"2. The Commanding Officer, 302nd Engineers, will detail officers to escort the visitors and show them all points of interest in camp. Immediately after arrival a review will be given in honor of the

American Society of Civil Engineers on the Engineer drill grounds. Following the review, the visitors will be taken through the barracks and mess halls of the Engineer regiment. Immediately afterwards there will be an exhibition of hand grenade practice and mining work by the Engineers.

"3. From the Engineer section, the visitors will observe a demonstration of bayonet combat under the supervision of Captain Brown, assisted by Sergeant Major Covington, of the British Army.

"4. The visitors, on the conclusion of the above practice, will be received by the Commanding General at Division Headquarters, at which time an opportunity will be given to view the camp from Lookout Tower.

"5. Luncheon will then be served at the Acker-Merrall-Condit Hotel; following which an exhibition infantry attack will be given by 'L' Company, 307th Infantry, followed by a machine gun demonstration given by the Machine Gun Co., 307th Infantry, at the machine gun butts near the gas house.

"6. Following the machine gun demonstration, a demonstration in the use of gas defence will be given at the gas house under the Officer in Charge of Gas Defence.

"7. The visitors will then be taken in trucks for a brief inspection of the Division target range, returning in time to entrain at 3:30 P. M.

"8. All arrangements will be under the direction of Colonel C. O. Sherrill, 302nd Engineers, with whom the officers in charge of demonstrations will confer as to details.

"By command of Brigadier General Johnson:

"WM. N. HASKELL,
"Major, Field Artillery,
"Acting Chief of Staff."

"Official:
"LLOYD C. GRISCOM,
"Adjutant General,
"Adjutant."

It will be seen from this that the matter of conducting the party, which is to visit Camp Upton to-morrow, has been taken out of the hands of the Committee of Arrangements, and is in better hands. It seems to me that this is perhaps not the time to express our thanks, but I do think it was a very nice thing for those people down there to turn the whole camp over to us to-morrow.

THE PRESIDENT.—Are the Tellers appointed to canvass the vote for officers ready to report, Mr. Ridgway?

ROBERT RIDGWAY, M. AM. SOC. C. E.—Yes, sir; shall I read the report?

THE PRESIDENT.—If you please.

"33 WEST 39TH ST.,
NEW YORK, N. Y.
JANUARY 16TH, 1918.

"TO THE SIXTY-FIFTH ANNUAL MEETING
AMERICAN SOCIETY OF CIVIL ENGINEERS:

"The Tellers appointed to canvass the ballots for Officers of the Society for 1918 report as follows:

"Total number of ballots received		1618
Ballots without signatures	16	
" stamped, not signed	7	
" from members in arrears of dues	5	
Total number not entitled to vote		28
Ballots canvassed		1590
Defective	0	

"*For President:*

ARTHUR N. TALBOT	1585
Scattering	5

"*For Vice-Presidents:*

JOHN F. COLEMAN	1572
NELSON P. LEWIS	1565
Scattering	9

"*For Treasurer:*

GEORGE W. TILLSON	1587
Scattering	2

"*For Directors:*

District No. 1	GEORGE W. GOETHALS	1539
	ANDREW M. HUNT	1536
	Scattering	14
District No. 4	SAMUEL TOBIAS WAGNER	1544
	Scattering	0
District No. 9	EDWARD E. WALL	1530
	Scattering	7
District No. 10	MILO S. KETCHUM	1539
	Scattering	1
District No. 11	HARRY HAWGOOD	1535
	Scattering	3

"ROBT. RIDGWAY
ALEXANDER HARING
T. C. CULYER
JAMES F. SANBORN
C. V. V. POWERS
S. H. WOODARD
F. W. GARDINER
Tellers."

THE PRESIDENT.—I declare the gentlemen, whose names have been read, elected to the various offices.

At the end of my term as President, I desire again to thank you for this great honor; I have not even yet learned to understand why it was accorded me. I also desire to thank the officers and the Board of Direction and the Members of the Society for their continuous and complete support in the duties which have devolved upon me.

I shall ask Past-Presidents Stearns and FitzGerald to escort the President to the Chair.

A. N. TALBOT, PRESIDENT, AM. SOC. C. E.—Members of the American Society of Civil Engineers. I thank you for this very generous reception. I do not quite find words to express my appreciation of the great honor you have conferred upon me in thus electing me to the Presidency of the American Society of Civil Engineers.

It is rightly regarded as the highest honor which can be conferred upon a Civil Engineer by his professional brethren. I have long had high esteem for the engineer's work, and for the responsible part he has taken in the development of the resources and the industries of this country; and I believe that in the future the part which he will play in the world's work will be even larger and more extended, and that the world will be brought to realize and to recognize more fully the work which the engineer should do for the world's welfare, and in this time of world war, in the outcome of which the engineer is taking so great a part—a war which must not be ended until it is ended right—the engineer has indeed a great responsibility to his country. When peace comes he may be expected to lead in the arts of peace, as he has done in the arts of war.

I am pleased to feel that my selection to this position is a recognition of the engineering teacher, that adjunct and co-partner in the Engineering Profession, who is striving to train young men to learn the art of engineering.

There is no one more enthusiastic about the work of the engineer, no one more devoted to its interests, than the engineering teacher. I thank you for this honor. With it, of course, comes responsibility. However, as I look forward to this, I am comforted by the fact that the Board of Direction, in whose hands the business of the Society is placed, is made up of twenty-nine other Members, who will have to share the responsibility.

I am sure that all the Members of the Board will be glad to have your suggestions, your criticisms, and your co-operation; and I feel that I can assure you that the officers of the Society and the Board of Direction have the interests of the Society at heart, and will do their best to carry on its business.

THE SECRETARY.—The only other announcement, Mr. President, that I think it is necessary to make, is that a meeting of the Board of Direction for organization will be held immediately on adjournment of this Meeting. The time specified was 1 o'clock. If the Board can meet before 1 o'clock, it would help matters very much, because its members want to go on that excursion and eat luncheon in the tunnel, which is an unusual experience for a Board.

The President.—The members of the Board will please take note of this.

A Member.—Where do they meet? In the Board Room?

The President.—In the Board Room.

There being no further business, I declare that the Annual Meeting is adjourned.

EXCURSIONS AND ENTERTAINMENTS AT THE SIXTY-FIFTH ANNUAL MEETING

Wednesday, January 16th, 1918.—After the Business Meeting, in the Engineering Societies Building, lunch for about 300 members was served.

At 1 P. M., through the courtesy of the Public Service Commission for the First District, D. L. Turner, M. Am. Soc. C. E., Chief Engineer, and P. McGovern and Company, A. A. Cohill, Chief Engineer, Contractors for building the Rapid Transit Tunnels, about 350 members visited and inspected Route 61, which forms a part of the 60th Street, East River, and Queens Plaza Route. The members were conveyed in automobile stages, and crossed the Queensboro Bridge to Queens Plaza, where they were the guests of the Contractor at luncheon in the tunnel.

At 8.15 P. M. there was a Theatre Party at the Hippodrome, and afterward a Supper-Dance at the Hotel Astor at which there was an attendance of about 225 members and guests.

Thursday, January 17th, 1918.—The day was devoted to an excursion to Camp Upton, Long Island. Through the courtesy of the Division Commander, an opportunity was afforded to the members of the Society and the members of their families to visit the camp. A special train, leaving the Pennsylvania Railroad Station at 9.30 A. M., conveyed the party, consisting of about 570 members and guests, to Camp Upton, arriving at 11.45 A. M.

Col. C. O. Sherrill, Commanding the 302d Engineer Regiment, detailed officers to escort the members and show them all points of interest. Immediately after arrival there was a review on the Engineer drill grounds in honor of the Society. Following the review the Commanding General addressed the members, and then the barracks and mess halls of the Engineer regiment were inspected, and there was an exhibition of hand grenade practice and mining work by the Engineers. In the hall of the Knights of Columbus the members witnessed a demonstration of bayonet combat under the supervision of Capt. Brown, assisted by Sergeant-major Covington, of the British Army.

The party was then given an opportunity to view the camp from Lookout Tower. Luncheon was served at the Acker-Merrall-Condit Hotel, following which there was an exhibition attack by "L" Company, 307th Infantry, and a machine-gun demonstration by the Machine Gun Company, 307th Infantry, and a demonstration in the use of gas defense.

The members entrained at 3.30 P. M. and arrived in New York at 6 P. M.

At 8.30 P. M. there was an illustrated lecture by Dougles W. Johnson, Associate Professor of Physiography, Columbia University, dealing with the topographic features of the terrain of northern and northeastern France, and with their influence on the strategy of the war. At this lecture about 700 members and guests were present. Following the lecture there was a social and informal Smoker, at which the attendance was about 800.

The following list contains the names of 750 members of various grades who registered as being in attendance at the Annual Meeting. The list is incomplete, as some members failed to register, and it does not contain the names of any of the guests of the Society or of individual members. It is estimated that the total attendance was about 1 200.

Abbott, C. P. . White Plains, N. Y.
Adams, E. G. . . . . New York City
Aertsen, G. . . . . . Philadelphia, Pa.
Aikenhead, J. R. . . New York City
Aims, W. I. . . . . . . New York City
Alexander, H. J. . . New York City
Allen, C. M. . . . . . Worcester, Mass
Allen, E. Y. . . . . . . New York City
Allen, F. W. Mount Vernon, N. Y.
Allen, Henry C. . . Syracuse, N. Y.
Allen, H. D. . . . . . . Newark, N. J.
Allen, Kenneth . . . New York City
Allen, L. E., Bellville, Ont., Canada
Alvord, J. W. . . . . Chicago, Ill.
Ammann, O. H., South Amboy, N. J.
Anderberg, Edward, New York City
Andrews, G. C. . . . . Buffalo, N. Y.
Armstrong, A. F. . . Albany, N. Y.
Ashbaugh, L. E. . New York City
Atkinson, A., New Brunswick, N. J.
Atwater, H. C. White Plains, N. Y.
Atwood, T. C. . . . . Atlantic, Mass.
Auryansen, F. . . . . Jamaica, N. Y.
Austin, W. E. . . . . New York City

Babcock, W. S. . . . New York City
Bailey, A. R. . . . . . New York City
Baird, H. C. . . . . . New York City
Bamford, W. B. . . . Belmar, N. J.
Barbour, F. A. . . . . . Boston, Mass.
Barnes, O. F. . . . Jersey City, N. J.
Barnes, T. Howard. New York City
Barnett, R. P. . . . . New York City
Barney, P. C. . . . . Brooklyn, N. Y.
Barney, S. E. . . New Haven, Conn.
Bartlett, W. A. . Waterbury, Conn.
Bartoccini, A. . . . . New York City
Barton, C. L. . . . . . New York City
Bascome, W. R. . . . New York City
Basinger, J. G. . . . New York City
Baum, George . . . . . Yonkers, N. Y.
Bean, E. D. . . . . Bridgeport, Conn.
Beardsley, J. W., East Orange, N. J.
Beck, R. E. . . . . . Brooklyn, N. Y.
Beebe, H. R. . . . . Utica, N. Y.
Beekman, J. V., Jr. . Boston, Mass.
Beggs, G. E. . . . . Princeton, N. J.
Belknap, J. M. . . . Brooklyn, N. Y.
Bellows, S. R. . . . . Brooklyn, N. Y.
Bennett, J. W. F. . New York City
Berger, Bernt . . . . . New York City
Bernegau, C. M. . . New York City
Besselievre, E. B. . Bayonne, N. J.
Betts, R. T. . . . . . . New York City
Beugler, E. J. . . . . New York City
Bevan, L. J. . . . . . . New York City
Bilyeu, C. S. . . . . . New York City
Binger, W. D. . . . . New York City

Bishop, G. W. . Newtonville, Mass.
Blackmore, G. G. . New York City
Blair, C. M. . . . New Haven, Conn.
Blakeslee, C. . . . New Haven, Conn.
Blakeslee, H. L. New Haven, Conn.
Blanchard, A. H. . New York City
Bleistein, B. J. . . . . Astoria, N. Y.
Boardman, C. S. . . . Buffalo, N. Y.
Boardman, H. E. . New York City
Boardman, W. H. . Newark, N. J.
Bogart, John . . . . . New York City
Bogert, C. L. . . . . . New York City
Boorman, K. M. . . New York City
Bornefeld, C. F. . . New York City
Boucher, W. J., Long Island City, N. Y.
Boughton, W. H., Poughkeepsie, N. Y.
Bouton, H. R. . . . . New York City
Brace, J. H. . . . . . . New York City
Bradbury, R. R., East Pleasantville, N. Y.
Bradley, F. E. . . . New York City
Brainard, A. S., Camp Upton, N. Y.
Bramwell, G. W. . New York City
Branne, J. S. Mount Vernon, N. Y.
Breed, H. E. . . . . . . Albany, N. Y.
Breitzke, C. F. . . . Boonton, N. J.
Brennan, J. G. . . . . . Albany, N. Y.
Brennan, J. L. . . . New York City
Breuchaud, Jules. . New York City
Briggs, W. C. . . . Brooklyn, N. Y.
Bringhurst, J. H. . Baltimore, Md.
Brodie, O. L. . . . . . New York City
Brooks, J. P. . . . . . Potsdam, N. Y.
Brown, Alfred T. . New York City
Brown, T. E. . . . . . New York City
Brown, W. E. . . . Brooklyn, N. Y.
Brownell, L. D. . Syracuse, N. Y.
Brush, W. W. . . . . New York City
Bryan, C. W. . . . . . New York City
Buck, H. R. . . . . . Hartford, Conn.
Buehler, Walter . . . . . Chicago, Ill.
Buel, A. W. . . . . . . New York City
Buettner, O. G. . . . New York City
Burpee, Moses . . . . . . Houlton, Me.
Burroughs, H. R. . New York City
Burrowes, Paul de N., Point Pleasant, N. J.
Bush, E. W. . . . . . Hartford, Conn.
Byers, B. B. F. . . . Pittsburgh, Pa.

Cadwallader, W. L. New York City
Carey, E. G. . . . Bridgeport, Conn.
Carle, N. A. . . . . Newark, N. J.
Carpenter, A. W. . New York City
Carpenter, C. E. . . Yonkers, N. Y.
Carpenter, S. T. M. . Buffalo, N. Y.
Carr, Albert. . East Orange, N. J.
Carson, H. Y. . . . . New York City
Carstarphen, F. C. . Trenton, N. J.
Case, J. F. . . . . New York City
Castleman, F. L. . . . Pencoyd, Pa.
Chadbourn, W. H. New York City
Chappell, T. F., Au Sable Forks, N. Y.
Chase, Charles F., New Britain, Conn.
Chase, Clement E., Poughkeepsie, N. Y.
Chase, R. D. . New Bedford, Mass.
Christian, G. L. . . Yonkers, N. Y.
Churchill, C. S. . . . . Roanoke, Va.
Clapp, S. K. . Grand Gorge, N. Y.
Clark, Watson G. . Tenafly, N. J.
Clarke, E. W. . Pleasantville, N. Y.
Clarke, G. C. . . . . . New York City
Clarke, St. John. . . . Bogota, N. J.
Class, C. Frank. . Harrisburg, Pa.
Clement, F. H. . Philadelphia, Pa.
Cleveland, H. B. . . . Albany, N. Y.
Closson, E. S. . . . Montclair, N. J.
Cobb, L. R. . . . . . . New York City
Coburn, H. L. . . . . New York City
Codwise, E. B. . . Kingston, N. Y.
Codwise, H. R. . Brooklyn, N. Y.
Coffin, T. A. . . . . Phœnixville, Pa.
Coffin, T. DeL. . . . Katonah, N. Y.
Cohen, A. B. . East Orange, N. J.

Cohen, F. W., Upper Montclair, N. J.
Cole, E. S........New York City
Cole, G. N........New York City
Cole, H. J...Averill Park, N. Y.
Collins, C. D.....New York City
Collins, T. E.....Elizabeth, N. J.
Conard, W. R..Burlington, N. J.
Conley, C. G. Mount Vernon, Ohio
Connell, H. L.....New York City
Connell, W. H..Philadelphia, Pa.
Connelly, J. A....New York City
Conover, C. E.....New York City
Constable, Howard, Kingston, Mass.
Constant, F. H..Princeton, N. J.
Conway, J. S..Washington, D. C.
Coombs, S. E.....New York City
Courtney, R. S....New York City
Coyne, H. L....Elmhurst, N. Y.
Crane, A. S......New York City
Crary, A. P......New York City
Critchlow, H. T...Trenton, N. J.
Crocker, H. S..Washington, D. C.
Crooks, C. H.....New York City
Cross, Hardy...Providence, R. I.
Cuddeback, A. W..Paterson, N. J.
Cullen, J. F....Philadelphia, Pa.
Culyer, T. C. Purdy Station, N. Y.
Cummings, R. A..Pittsburgh, Pa.

Dakin, A. H., Jr..New York City
Datesman, G. E. Philadelphia, Pa.
Davies, J. V......New York City
Davis, A. L.......New York City
Davis, A. P...Washington, D. C.
Davis, B. H......New York City
Davison, G. S.....Pittsburgh, Pa.
Delson, Isidore..Stapleton, N. Y.
Develin, R. G...Philadelphia, Pa.
De Witt, P. H.....Newark, N. J.
de Wyrall, Cyril, Ridgefield Park, N. J.
Dilks, L. C.......Milliken, N. Y.
Dingman, C. F....Palmer, Mass.
Dodge, J. L.....Jamaica, N. Y.
Dodge, S. D.......Mahwah, N. J.
Donham, B. C....New York City
Dorrance, W. T., New Haven, Conn.
Dougherty, R. E., White Plains, N. Y.
Doyen, G. E.....New York City
Drinkwater, E., St. Lambert, Que., Canada
Dunham, H. F...New York City
Durfee, J. J.....Brooklyn, N. Y.
Dutton, C. H...Providence, R. I.

Earle, Thomas....Bethlehem, Pa.
Easby, M. W....Philadelphia, Pa.
Eberly, V. A...Washington, D. C.
Eckersley, J. O...New York City
Eddy, H. P. Newton Center, Mass.
Edwards, D. G......Hollis, N. Y.
Edwards, W. R., Washington, D. C.
Eide, Torris......New York City
Elwell, C. C...New Haven, Conn.
Emerson, K. B....New York City
Evans, E. G., Moncton, N. B., Canada
Evers, Rudolph..Brooklyn, N. Y.

Fairlie, J. W.....New York City
Farley, J. M..White Plains, N. Y.
Farnham, A. B..Pittsfield, Mass.
Farnham, R.....Philadelphia, Pa.
Fay, F. H..........Boston, Mass.
Federlein, W. G., Rockville Centre, N. Y.
Felgenhauer, F. J. New York City
Files, T. H......New York City
Fisher, E. A....Rochester, N. Y.
Fisher, H. T...Englewood, N. J.
Fitch, H. A....Kansas City, Mo.
FitzGerald, Desmond, Boston, Mass.
FitzRandolph, W. S., New York City

Fletcher, Robert..Hanover, N. H.
Flinn, A. D......New York City
Forbes, F. B.....New York City
Ford, F. L....New Haven, Conn.
Ford, Harry C....New York City
Ford, W. H....Philadelphia, Pa.
Foss, F. E........New York City
Foster, E. H......New York City
Fowler, C. E......New York City
Fox, W. F. Rockville Centre, N. Y.
Frank, A. H.....Brooklyn, N. Y.
Franklin, C. M., Mount Vernon, N. Y.
Freeman, M. H...New York City
French, J. B......New York City
Frommer, Charles, Philadelphia, Pa.
Fuller, A. H.........Easton, Pa.
Fuller, F. L...New Haven, Conn.
Fuller, G. W.....New York City
Fuller, W. E..Dobbs Ferry, N. Y.

Gadd, R. F......Hartford, Conn.
Gailor, C. F......New York City
Gambier-Bousfield, G. E., New York City
Gandolfo, J. H...New York City
Gardiner, F. W...New York City
Gardiner, J. deB. W., New York City
Gardner, H. C....Lancaster, Pa.
Gardner, Warren..New York City
Gaston, L. P......New York City
Gay, H. S........Westfield, N. J.
Giesey, J. K......New York City
Gifford, G. E......New York City
Gildersleeve, A. C. New York City
Gillen, W. J......New York City
Gilman, Charles...New York City
Gladding, H. H..New Haven, Conn.
Glander, J. H., Jr..New York City
Glover, P. H......New York City
Golding, T. W.....New York City
Goldmark, Henry..New York City
Goldsborough, J. B., Croton-on-Hudson, N. Y.
Goodrich, C. R......Utica, N. Y.
Goodrich, E. P....New York City
Gould, C. M.......New York City
Gould, R. R.......New York City
Granbery, J. H....New York City
Gray, William.....New York City
Greene, G. S., Jr..New York City
Greenlaw, R. W...New York City
Greenwood, E. E. Skowhegan, Me.
Gregory, C. E...Mt. Kisco, N. Y.
Gregory, J. H.....New York City
Gregson, A. C.....New York City
Greiner, J. E......Baltimore, Md.
Griffin, G. A...Washington, D. C.
Groat, B. F.......Pittsburgh, Pa.
Grove, W. G......New York City
Grover, W. A.......Dover, N. H.
Gunther, C. O....Hoboken, N. J.

Haas, P. L.......New York City
Haight, H. de R...New York City
Haines, E. G., Richmond Hill, N. Y.
Hallock, J. C......Newark, N. J.
Halsey, W. H. Southampton, N. Y.
Hammond, G. T..Brooklyn, N. Y.
Hansel, Charles...New York City
Harby, Isaac......New York City
Harding, H. S......Hollis, N. Y.
Haring, Alexander, New York City
Harrington, A. W. Yonkers, N. Y.
Harrington, W...New York City
Harte, C. R...New Haven, Conn.
Haskins, W. J....New York City
Hatt, W. K.....La Fayette, Ind.
Hauck, William...New York City
Havens, W. W.....New York City
Hayes, M. D......New York City
Hayes, R. D....Stillwater, N. Y.
Hazen, W. N.......Orange, N. J.
Headley, W. T..Philadelphia, Pa.
Heiser, A. B......Brooklyn, N. Y.

Heiser, W. J......Brooklyn, N. Y.
Heller, J. W. South Orange, N. J.
Henderson, A. R., Jersey City, N. J.
Henry, P. W......New York City
Hering, Rudolph..New York City
Hermanns, F. E...New York City
Herschel, Clemens. New York City
Hess, E. W........Clearfield, Pa.
Hewes, V. H......New York City
Hewett, B. H. M...New York City
Hickok, H. A......Newark, N. J.
Higgins, C. H.....New York City
Higgins, J. W....New York City
Hill, H. C....Binghamton, N. Y.
Hill, N. S., Jr...New York City
Hinds, A. K.........Chester, Pa.
Hodgdon, B. A. East Orange, N. J.
Hodgdon, F. W.....Boston, Mass.
Hoff, Olaf........New York City
Holbrook, A. R..Brooklyn, N. Y.
Holbrook, Percy...New York City
Holden, C. A.....Hanover, N. H.
Holland, C. M....Brooklyn, N. Y.
Holmes, G. D....Syracuse, N. Y.
Holmes, N. H.....New York City
Holtzman, S. F., Hastings-on-Hudson, N. Y.
Hoover, A. P....New York City
Hormel, A. A....Brighton, Mass.
Horne, H. W..Collinsville, Conn.
Houston, J. J. L. Philadelphia, Pa.
Howard, L. T....New York City
Howe, C. E., Hastings-on-Hudson, N. Y.
Howell, R. P..Phillipsburg, N. J.
Howell, W. A......Newark, N. J.
Hoyt, J. C....Washington, D. C.
Hudson, C. W., Upper Montclair, N. J.
Humphrey, R. L. Philadelphia, Pa.
Humphreys, A. C. New York City
Hunt, A. M.......New York City
Hunt, C. A......Brooklyn, N. Y.
Hunt, C. E.......New York City
Hunt, Chas. Warren, New York City
Hurd, H. L..White Plains, N. Y.
Hurlbut, C. C...Montclair, N. J.
Hutchins, E......New York City

Ingersoll, C. M...New York City

Jackson, J. F..New Haven, Conn.
Jacobs, R. H., Harrington Park, N. J.
Jewett, T. E......New York City
Joachimson, M...New York City
Johannesson, S., Upper Montclair, N. J.
Johnson, A. N.......Chicago, Ill.
Johnson, G. A.....Newark, N. J.
Johnson, N. C.....New York City
Jones, G. R.......Baltimore, Md.
Jones, H. L.......New York City
Joseph, J........Brooklyn, N. Y.

Karner, W. J.....New York City
Keays, R. H....Jersey City, N. J.
Keith, H. C......New York City
Keller, O. B......New York City
Kelley, W. D......Yonkers, N. Y.
Kelly, C. W...New Haven, Conn.
Kennedy, *Sir* John, Montreal, Que., Canada
Kershaw, W. H...New York City
Ketchum, M. S.....Boulder, Colo.
Khuen, R., Jr....Pittsburgh, Pa.
Kimball, F. C.....Summit, N. J.
Kienle, J. A.....New York City
Kinney, W. M.......Chicago, Ill.
Kinsey, W. A......Newark, N. J.
Kirkwood, H. C..Flushing, N. Y.
Kittredge, G. W..New York City
Knickerbocker, C. E., Washington, D. C.
Knight, H. M..Providence, R. I.
Knighton, J. A..New York City
Knowles, M.......Pittsburgh, Pa.
Knox, S. B.......New York City
Knutson, G. H....Jackson, Mich.

Kolb, H. J.......Brooklyn, N. Y.
Kornfeld, A. E....New York City
Kraus, A........Brooklyn, N. Y.
Krause, M. C...Williamsport, Pa.
Krone, A. H......Baltimore, Md.
Kuchar, F. M....Brooklyn, N. Y.

La Chicotte, H. A. Brooklyn, N. Y.
Landreth, O. H., Schenectady, N. Y.
Landreth, W. B., Schenectady, N. Y.
Lang, F. A.......New York City
Lange, T. F......New York City
Langthorn, J. S..Brooklyn, N. Y.
Larsson, C. G. E..Plainfield, N. J.
Lathrop, H. M...Caldwell, N. J.
Lawrence, E. V...New York City
Leavitt, C. W.....New York City
Lee, W. B........New York City
Leete, P. R........Boston, Mass.
Leighton, G........Lyons, N. Y.
Leiser, F. Jr.....Longport, N. J.
Leser, H.........New York City
Lesley, R. W....Philadelphia, Pa.
Lewis, N. P......New York City
Lex, W. I......Philadelphia, Pa.
Liebmann, A.....New York City
Linsley, C. W......Oswego, N. Y.
Lobo, C..........Brooklyn, N. Y.
Logan, W. S.......Newark, N. J.
Loomis, H........New York City
Lowinson, O......New York City
Lucas, G. L.......New York City
Ludwig, J. A......New York City
Lundie, J.........New York City

MacCornack, C. W., Phœnixville, Pa.
MacDonald, C.....Trenton, N. J.
MacFeeters, J. O., Glen Ridge, N. J.
MacGregor, R. A..New York City
Machen, H. B....New York City
McCarthy, D. F. Bronxville, N. Y.
McClintock, J. R..New York City
McCollough, C. A. New York City
McDowell, F. F..Yonkers, N. Y.
McGrew, A. B....Pittsburgh, Pa.
McHenry, E. H., New Haven, Conn.
McIntyre, W.......Ardmore, Pa.
McMinn, T. J....Brooklyn, N. Y.
McNeal, J............Easton, Pa.
McNulty, G. W...New York City
McPherson, R. H. New York City
Madden, J. H.....New York City
Manahan, E. G...New York City
Manley, H., Jr....New York City
Manley, L. B...Philadelphia, Pa.
Marsh, F. B......Tuckahoe, N. Y.
Martin, E. S......New York City
Mason, F.........New York City
Matlaw, I. S..Camp Meade, Md.
Mattimore, H. S..Albany, N. Y.
Mayell, A. J......New York City
Mead, C. A., Upper Montclair, N. J.
Meadowcroft, W..New York City
Mebus, C. F....Philadelphia, Pa.
Meem, J. C......Brooklyn, N. Y.
Mehren, E. J......New York City
Melius, L. L......New York City
Mensch, L. J.........Chicago, Ill.
Meriwether, C........Chicago, Ill.
Merriman, M.....New York City
Merriman, T......New York City
Merryman, W. C..New York City
Metcalf, L..........Boston, Mass.
Michael, H. L.....Auburn, N. Y.
Michael, W. W..Kingston, N. Y.
Michener, H. P. Mt. Vernon, N. Y.
Miller, A. B.....Montclair, N. J.
Miller, M. M......Yonkers, N. Y.
Miller, M. S.....Brooklyn, N. Y.
Miller, R. P......New York City
Miller, S. F..South Orange, N. J.
Mitchell, S. P...Philadelphia, Pa.
Modjeski, R.......New York City
Mogensen, O. E...New York City

Moisseiff, L. S....New York City
Monsarrat, C. N., Montreal, Que., Canada
Moore, F. F......New York City
Moore, W. H..New Haven, Conn.
Morgan, T. C....Brooklyn, N. Y.
Morrison, H. P., West New Brighton, N. Y.
Morse, C. F..Good Ground, N. Y.
Morse, W. L......New York City
Moyer, A.........New York City
Muir, J. C........New York City
Myers, J. H.......New York City

Neely, J. T.........Norfolk, Va.
Nelson, J. W....Brooklyn, N. Y.
Neumeyer, R. E...Bethlehem, Pa.
Newcomb, W. T......Easton, Pa.
Newkirk, S. F., Jr.Bayside, N. Y.
Noble, F. C......New York City
Norris, W. H......Portland, Me.
North, A. T......New York City
Norton, A. G..Middletown, N. Y.

Oakley, G. I...Little Falls, N. Y.
Odell, F. S....Port Chester, N. Y.
Ogden, H. N.......Ithaca, N. Y.
Okeson, W. R., South Bethlehem, Pa.
Olcott, E. E.......New York City
Olmsted, A. E.....New York City
O'Rourke, J. F....New York City
Orrok, G. A.......New York City
Ott, S. J.......Rutherford, N. J.
Owen, J...........Newark, N. J.
Oxholm, T. S., New Brighton, N. Y.

Paddock, H. C.....New York City
Paine, H. A.......New York City
Parker, C. J......New York City
Parker, J. L.......New York City
Parlin, R. W.....Brooklyn, N. Y.
Parsons, H. De B..New York City
Payrow, H. G....Bethlehem, Pa.
Pegram, G. H....New York City
Pendlebury, E....Arlington, N. J.
Perkins, E. T........Chicago, Ill.
Perkins, W. W. C.Conneaut, Ohio
Perrine, G........New York City
Perry, F. W......New York City
Perry, J. P. H....New York City
Perry, L. E........Trenton, N. J.
Pett, C. E........New York City
Peverley, R. St. L..New York City
Pfau, J. W.......New York City
Phillips, A. E..Washington, D. C.
Phillips, A. L...Philadelphia, Pa.
Phillips, H. C...Philadelphia, Pa.
Phillips, J. H..Glen Ridge, N. J.
Plumer, H. E....New York City
Pohl, C. A........New York City
Pollock, C. DuB...New York City
Pommerer, R. W., White Plains, N. Y.
Pond, F. H.......New York City
Pond, H. O.......New York City
Poore, H. C., East Braintree, Mass.
Porter, J. E......Yonkers, N. Y.
Porter, J. M.........Easton, Pa.
Post, C. W.........Albany, N. Y.
Powell, C. U....Flushing, N. Y.
Powers, C. V. V..New York City
Pratt, F. E.......New York City
Preston, H. W.....Elmira, N. Y.
Price, F. O.......Brooklyn, N. Y.
Priest, B. B......New York City
Purver, G. M....Brooklyn, N. Y.

Quimby, C. H., Jr., Washington, D. C.
Quimby, H. H..Philadelphia, Pa.
Quincy, C. F.....New York City

Randorf, C. A.....Buffalo, N. Y.
Rankin, E. S......Newark, N. J.
Rapalje, DeW..East Orange, N. J.
Reed, H. B.......New York City
Ray, G. J........Hoboken, N. J.

Reed, W. B.......New York City
Reeves, W. F.....New York City
Reid, H. A......Brooklyn, N. Y.
Reidpath, R. J.....Buffalo, N. Y.
Reimann, R..........Relay, Md.
Reynolds, J. O...Brooklyn, N. Y.
Rice, G. S........Brooklyn, N. Y.
Richardson, C....New York City
Richardson, J. D..Corona, N. Y.
Richardson, R. D...Scranton, Pa.
Richmond, J. P. W., New York City
Ridgeway, R......New York City
Rights, L. D......New York City
Ripley, H. L.......Boston, Mass.
Robbins, F. H....New York City
Roberts, H. W....New York City
Roberts, T. C..East Orange, N. J.
Robinson, G. L....New York City
Robson, R. H.....New York City
Rodman, G. E.....New York City
Rogers, A. W.......Buffalo, N. Y.
Rogers, E. H. West Newton, Mass.
Rohde, C. F.....Brooklyn, N. Y.
Rohrer, J. B.......Lancaster, Pa.
Ruckes, J. J., Jr..New York City
Rugg, W. F..White Plains, N. Y.
Rumery, R. R....New York City
Ryan, M. H......New York City
Ryder, E. M. T...New York City

Sackett, A. J.....New York City
Sackett, R. L..State College, Pa.
Sacks, S. I......Philadelphia, Pa.
Sampson, G. A.....Boston, Mass.
Sanborn, F. B......Boston, Mass.
Sanborn, J. F....New York City
Saville, C. M....Hartford, Conn.
Sax, P. M......Philadelphia, Pa.
Schaeffer, A......New York City
Schermerhorn, H. O., Albany, N. Y.
Schmidt, M. E...New York City
Schneeweiss, A. E..Clifton, N. J.
Schofield, H. A..Philadelphia, Pa.
Schwarze, C. T...New York City
Schweizer, R., Jr., Ridgefield Park, N. J.
Schwiers, F. W., Jr., New York City
Scott, W. V......Flushing, N. Y.
Seaman, H. B. Washington, D. C.
Seabury, G. T...Providence, R. I.
Seaman, W. H..Glen Cove, N. Y.
Searle, C. D......New York City
Selby, O. E.....Cincinnati, Ohio
Serber, D. C......New York City
Shailer, R. A.....New York City
Shaw, A. M.....New Orleans, La.
Shaw, G. H. T.......Chicago, Ill.
Sheldon, P.......Hartford, Conn.
Shelley, H. T...Philadelphia, Pa.
Shenehon, F. C., Minneapolis, Minn.
Sherman, A. L...Mansfield, Mass.
Sherrerd, M. R....Newark, N. J.
Sherron, G. A....Norwalk, Conn.
Shertzer, T. B....New York City
Shoemaker, L. H..Pittsburgh, Pa.
Shoemaker, M. N..Newark, N. J.
Sieling, L. J.....Red Bank, N. J.
Sikes, Z. H.......Yonkers, N. Y.
Simpson, C. R....New York City
Sitt, W. T........New York City
Skillin, E. S......New York City
Skinner, J. F....Rochester, N. Y.
Sloan, S. A.....Philadelphia, Pa.
Smith, A.........Bayonne, N. J.
Smith, C. Elmore, New Brighton, N. Y.
Smith, V. C........Dayton, Ohio
Smith, F. V......New York City
Smith, H. E..Binghamton, N. Y.
Smith, H. S....Wilkes-Barre, Pa.
Smith, J. Waldo..New York City
Smoley, C. K.......Scranton, Pa.
Smoyer, L. I..Woodhaven, N. Y.
Snell, H. B......Brooklyn, N. Y.
Snell, T. C. B....New York City
Snow, J. B....Forest Hills, N. Y.

Spaulding, C. L..New York City
Spear, W. E..Camp Upton, N. Y.
Sperry, H. M.....New York City
Spilsbury, E. G...New York City
Splitstone, C. H...New York City
Spooner, R. N.....New York City
Stark, C. W......New York City
Starr, H. H....Philadelphia, Pa.
Stearns, F. L.....New York City
Steffens, W. F....New York City
Stein, J. B......Brooklyn, N. Y.
Steinhauser, H. H., Brooklyn, N. Y.
Steinman, D. B...New York City
Stengel, C. H.....New York City
Stephens, A. W...New York City
Stevens, C. H...Philadelphia, Pa.
Stevenson, W. F., New Rochelle, N. Y.
Stiles, A. I......New York City
Stevens, C. H...Philadelphia, Pa.
Stevens, H. C....New York City
Stoddard, R. F....Milford, Conn.
Stone, S. J....Garden City, N. Y.
Stowitts, G. P....Yonkers, N. Y.
Strachan, J......Brooklyn, N. Y.
Stuart, E........Harrisburg, Pa.
Swift, W. E..New Canaan, Conn.
Swindells, J. S...New York City

Taber, G. A.....Brooklyn, N. Y.
Talbot, A. N........Urbana, Ill.
Talbot, F. M....Glen Ridge, N. J.
Talbot, K. H.....Pittsburgh, Pa.
Taylor, C. F.....New York City
Taylor, W. G.....Newark, N. J.
Terry, J. H....Philadelphia, Pa.
Thacher, E.......New York City
Thayer, N. E.....New York City
Thomes, E. H....Jamaica, N. Y.
Thompson, S. C..New York City
Thomson, A. Jr., East Orange, N. J.
Thomson, T. Kennard, New York City

Tidd, A. W...White Plains, N. Y.
Tilden, C. J......Baltimore, Md.
Tillson, G. W....Brooklyn, N. Y.
Timberlake, S. M..Brooklyn, N. Y.
Tinker, G. H....Cleveland, Ohio
Tomlinson, C. P..Hartford, Conn.
Tower, J. W......New York City
Tretter, G. A......Roanoke, Va.
Tribus, L. I......New York City
Triest, W. G.....New York City
Trout, C. E., West New Brighton, N. Y.
Trow, F. H......Kingston, N. Y.
Tucker, L. W.....New York City
Tull, R. W.......New York City
Tuska, G. R.....New York City
Tuttle, A. S......New York City
Tye, W. F. Montreal, Que., Canada

Ungrich, M. J....New York City
Upton, J........Flushing, N. Y.

Vallely, W. P....Brooklyn, N. Y.
Value, B. R......New York City
Van Horne, J. G..New York City
Vincent, J. I......New York City
Vinton, T. M.....New York City
Voetsch, C..........Utica, N. Y.
Voynow, C. B...Philadelphia, Pa.

Waddell, J. A. L...Kansas City, Mo.
Wadsworth, J. E..New York City
Wagner, S. T...Philadelphia, Pa.
Wahlman, P......New York City
Wait, B. H......New York City
Waite, D. C......Brooklyn, N. Y.
Waite, G. B......New York City
Walker, C. I......New York City
Walker, J. J..Dobbs Ferry, N. Y.
Walton, H. C......Boston, Mass.
Ward, E. A....Jersey City, N. J.
Wardle, E. B., Grand Mere, Que., Canada
Warnock, W. H..Edgemere, N. Y.
Wasser, T. J...Jersey City, N. J.

Watson, C. H. .Great Neck, N. Y.
Watson, R. M. .Rutherford, N. J.
Webster, A. L. . . .New York City
Webster, G. S. . .Philadelphia, Pa.
Wegmann, E. . . . .New York City
Weiskopf, S. C. . . .New York City
Wells, C. E. .White Plains, N. Y.
Wells, G. E. . . .Naugatuck, Conn.
Welty, H. T. . . . . .New York City
Wendt, E. F. . .Washington, D. C.
Wentworth, C. A. . . .Wayne, Pa.
Weymouth, A. . . .Flushing, N. Y.
Wheatcroft, H. B., Jr., New York City
Whipple, G. C. .Cambridge, Mass.
Whitcraft, L. N.Hackensack, N. J.
White, L. . . . . .New York City
White, T. S. . . .Beaver Falls, Pa.
Whitney, G. C. . . .Brooklyn, N. Y.
Whittier, T. T. . .Brooklyn, N. Y.
Wich, B. . . . . .Brooklyn, N. Y.
Wickham, H. R. .Brooklyn, N. Y.
Wiggins, R. R. .Garden City, N. Y.
Wilcock, F. . . . . .Brooklyn, N. Y.
Wiley, W. H. . . . .New York City
Williams, C. G. .Plainfield, N. J.
Williams, G. S. .Ann Arbor, Mich.
Williams, J. P. J. .New York City
Willoughby, J. E., Wilmington, N. C.

Wilmot, J. . . . . . . .New York City
Wilmot, S. . . . . . . .New York City
Wilson, T. L. . .Canterbury, Conn.
Winsor, F. E. . . .Providence, R. I.
Winsor, G. A. .Pleasantville, N. Y.
Winsor, H. D. .Westerleigh, N. Y.
Wise, C. R. . . . . . . .Passaic, N. J.
Wise, R. S. . . . . . . .Passaic, N. J.
Witmer, F. P. .East Orange, N. J.
Wolfe, F. C. . . .Bridgeport, Conn.
Wolfe, F. G. . . . . . . .Scranton, Pa.
Wölfel, P. L. . . . . .Pittsburgh, Pa.
Wolff, A. D., Jr. . . .Hudson, N. Y.
Wolff, R. B. . . . . .New York City
Wolpert, O. . . . . . .New York City
Woodard, S. H. . .New York City
Woodcock, H. W. .Brooklyn, N. Y.
Wortendyke, N. D., Jersey City, N. J.
Wyckoff, C. R. . .Hartsdale, N. Y.
Wyman, A. M. .Philadelphia, Pa.

Yates, C. C. . . . . . .New York City
Yates, P. K. . . . . . .New York City
Yates, W. H. . . . . .New York City
Yereance, W. B. .New York City
Young, C. G. . . . .New York City

Zipser, M. E. . . . . .New York City

SOCIETY ITEMS OF INTEREST

Relations Between the Canadian Society of Civil Engineers and This Society

The following resolutions, adopted by the Council of the Canadian Society of Civil Engineers, at its meeting on November 27th, 1917, in reply to the resolutions adopted by the Board of Direction of the American Society of Civil Engineers,* are printed here for the information of the membership:

"*Whereas*, the Council of the Canadian Society of Civil Engineers has received a copy of the Resolution adopted by the Board of Direction of the American Society of Civil Engineers at a meeting held on October 9th, 1917, expressing the desirability of the closest co-operation and cordial relationship between the American Society of Civil Engineers and the Canadian Society of Civil Engineers, and

"*Whereas*, the Council of the Canadian Society of Civil Engineers is in full accord with the sentiments and principles so clearly enunciated in the said Resolutions, therefore be it

"*Resolved*, that the Council of the Canadian Society of Civil Engineers record its hearty appreciation and express its thanks to the Board of Direction of the American Society of Civil Engineers for the kindly interest shown by the Resolutions, and be it further

"*Resolved*, that the Council of the Canadian Society of Civil Engineers co-operate with the Board of Direction of the American Society of Civil Engineers to the end that the terms of the said resolution may be carried into effect, and that the Council reciprocate the action of the Board by inviting the members of the American Society of Civil Engineers to take advantage of the facilities offered by the Canadian Society of Civil Engineers and make themselves at home in its rooms and attend its meetings whenever they may visit Montreal.

"*Be it further Resolved*, that a Committee of the Canadian Society of Civil Engineers, consisting of the President, Past-President, and two members of the Council, be requested to communicate with the Board of Direction of the American Society of Civil Engineers with a view to making arrangements for giving effect to the terms of the said Resolution, and further,

"*That* a copy of these Resolutions be sent to the Board of Direction of the American Society of Civil Engineers."

Professional Classes War Relief

The following letter from the Secretary of the Professional Classes War Relief of America has been received by the Secretary, and is published for the information of the membership.

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* *Proceedings*, Am. Soc. C. E., Vol. XLIII, p. 642 (November, 1917).

"JANUARY 29, 1918.

"MR. CHAS. WARREN HUNT,
"*Secy., American Society Civil Engineers,*
"33 West 39th St.,
"New York City.

"DEAR MR. HUNT:

"Our Organization has reached the point where we are prepared for active relief of professional men who have enlisted, who are in the civil service, who are in civilian life, or of the families of such.

"The main obstacle to such relief is the hesitancy of this class to make known their needs. Relief cases have to be sought out. We have found some cases. Many more exist. We ask you to co-operate with us by making, through your organization, the following inquiries:

"(1) Do you know of any cases, civilian or otherwise, where relief is needed by a professional man or his family?

"(2) Will you make it your business to inform your brother professionals of this war relief, and not only to be on the alert for all situations deserving relief, but in view of the difficulty of contact with them, to make all possible inquiry as to such situations?

"(3) Will you inform us immediately of all such cases as may come to your attention?

"For your co-operation accept our thanks and that of those whom we shall help through such co-operation.

"Very sincerely yours,
"CARRINGTON PHELPS,
"*Secretary.*"

Student Branches

The following report is printed for the information of the membership.

"JANUARY 9, 1918.

"TO THE BOARD OF DIRECTION,
"AMERICAN SOCIETY OF CIVIL ENGINEERS.

"Your committee appointed to investigate the wisdom of establishing Student Branches of the Society begs to report:

"1. That the activities of its members on account of the war have precluded a ready getting together for the consideration of the subject.

"2. That while the correspondence with members of the Society is on the whole favorable to the establishment of such Student Branches there are well disposed objections to such action.

"Those favorable to the project give as a reason the good of the Society by creating an interest in it among prospective engineers while young. Those objecting, while conceding good to the Society, claim that a greater good would result to the profession, and ultimately to the Society, by leaving the student free to pursue more general subjects rather than concentrate on strictly professional subjects.

"3. That the greatly decreased attendance in engineering colleges due to the war, and the necessity of preparing young men as speedily as possible to do their part in the war, makes this an inopportune time to inaugurate such a policy, even should it be decided wise under normal conditions.

"4. Under the circumstances, your committee recommends that further consideration and report be deferred until after the close of the war; or, indefinitely postponed."

"Respectfully,
"M. E. COOLEY,
"Chairman."

"COMMITTEE:
"M. E. COOLEY,
"WILLIAM CAIN,
"CHARLES D. MARX,
"GEORGE F. SWAIN,
"JOHN L. VAN ORNUM."

Hydro-Electric Development

Statement submitted to a special committee of the United States Chamber of Commerce, January 14th, 1918, on behalf of Engineering Council, by Calvert Townley, Esq.

"It is my pleasant duty to appear before you by vote of the Executive Committee of Engineering Council, in response to your kind invitation of January 10th. Being empowered, as it is, to speak for the American Society of Civil Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, on matters of common concern to all these bodies, Engineering Council's official utterances concern only such underlying principles and economic facts as are endorsed by all engineers and beyond the field of controversy. These Societies are scientific and professional. They, therefore, refrain from expressing views on legal, political, and commercial questions, except when such are closely linked with essential engineering facts. The statements which I am privileged to make to you are not expressions of my personal views, nor of those of any group. They have been submitted to, and approved by, the Executive Committee of Engineering Council which believes them to fall within the definition given.

"The introduction of electricity as a means for transmitting power over considerable distances, and its subsequent rapid development, completely changed the status of hydraulic power. Previously such power could only be used near falling water. Now it is commercially available in convenient form within a radius, in some instances, up to 200 miles, a fact that has made it possible to utilize water powers even when located in remote and inaccessible places. Indeed, to-day practically all hydraulic power developments of any magnitude are hydro-electric. Along with improvements in the art of electrical transmission have come equally rapid developments in the application of electricity. Electric light has become almost the universal illuminant. Electric motors largely drive our factories and propel all our street cars. They have made substantial progress in replacing steam locomotives on some large railroads, while the manufacture of nitrogenous products for explosives and fertilizers, and of such products as abrasives and aluminum, depends for its commercial success on electro-chemistry. In an endeavor to supply the demand for electric current thus created, large central generating stations have been established in or near all large centers of population.

"In the light of the foregoing, it might seem reasonable to suppose that a large proportion of the modern demand for electric current would be supplied from the energy in falling water. Such, however, is not the case. Accurate statistics are difficult to obtain, but some approximate totals may prove illuminating. It has been estimated by a careful engineer that in 1911 there was more than 26 000 000 steam-engine horse-power capacity in use (including railroad locomotives) in the United States. The aggregate water horse-power developed and undeveloped has been computed as around 60 000 000. Of this latter, the U. S. Census of 1912 gives 4 870 000 as developed, and, in a report of January, 1916, the Secretary of Agriculture estimates this total to have been increased to 6 500 000. Making liberal allowances for correction in these several figures, it seems probable that there are in service from four to five times as many steam as water horse-powers, and that there are still undeveloped water horse-powers equal to at least twice that of all the steam capacity in service. Some of the undeveloped power sites are too remote from any market to be now utilized, and an uncertain number are not commercial prospects; but, even so, it is clear that the possibilities of additional development are very great.

"There are two fundamental causes which have militated against the substitution of hydro-electric for steam-electric power. One is economic and permanent; the other is statutory, and therefore subject to modification. Both reasons apply to some powers, but neither, fortunately, to all. The economic and permanent reason is high cost of development due to natural conditions. Electric power generated by falling water is inferior to that generated by steam in every particular except cost, and, therefore, water-driven service must be cheaper than steam-driven, in order to justify its existence. The price for service depends primarily on cost, and cost divides itself naturally into two main items, namely, operation (including maintenance), and fixed charges. As an hydro-electric plant consumes no fuel, its operating cost is less than that of an equivalent steam-driven plant. On the other hand, a steam plant costs usually only from one-fifth to one-half as much per unit of capacity as an hydro-electric plant; so that the latter must carry very much heavier fixed charges. This disability of water service is usually even greater than the ratio of the costs of two equivalent complete developments. A power enterprise seldom comes into being with a market for its entire ultimate output. Therefore, when steam is to be the motive power, only such capacity is installed as initial demands require, and the cost per unit is fairly proportional to that of the ultimate development. In a water development, on the contrary, a larger part of the cost is for riparian rights, for the dam, impounding reservoir, flume, forebay, etc., and for the transmission right of way, towers, etc., which must be, at the start, largely provided and constructed for the complete installation. The obvious result is a greater fixed charge per unit of capacity and a higher cost per horse-power delivered for sale. In forecasting the commercial prospects of a power enterprise, the possible market must be studied, and, of course, a sale price for power decided upon. As this price is controlled by the cost of similar service from other sources, usually from steam, and as it must be attractive from the start, the additional burden of fixed charges on the initial part of an hydro-electric installation frequently forces the sale of its power below cost. The projectors of the enterprise then must rely for success on a sufficient subsequent increase in their markets. The possibility of an incorrect forecast of the extent of such increase and of the time when it may come imposes a serious business hazard against water and in favor of steam.

"It has been frequently pointed out that, as the Nation's coal supply is depleted, the cost of coal must rise, thus increasing the cost of steam-electric power as a competitor and raising the market value of hydro-electric power accordingly. The rising price of coal is a matter of record, but it is not so generally known that the improved efficiency of steam-producing machinery (boilers, engines, generators, and auxiliaries) has more than kept pace, so that the net cost of producing electric power from coal has steadily declined. As applied to the pre-war period, it may be stated that, over a period of 10 years, the cost of coal has risen on an average 1% per year, while the cost of electric power produced from coal has fallen on an average 2½% per year. In addition to these facts—still referring to pre-war conditions—the cost of steam-electric generating equipment has been greatly reduced. This fact is due partly to the introduction and subsequent improvement of the steam turbine, and in part to the great increase in the size of the units now available. There is nothing to indicate that the limit of improvement in the design of steam prime movers has been reached, or is even in sight. It is, therefore, a reasonable assumption that further advances in the art will continue to occur and to cut down both the fixed charges and the operating cost of steam power as a competitor of water. The largest modern steam turbine has now some twelve times the capacity which the largest reciprocating engine had 15 years ago. Stated another way, the cost of a steam-electric plant per unit of capacity just before the war was about one-third of what it was 15 years previously, while the energy it produces per pound of coal has increased 50 per cent. In addition to the development of steam prime movers, the Diesel or the internal combustion engine is now coming largely into use as a further competitor of water power where fuel oil is available, as in the southwestern district of the United States. The efficiency of these engines is considerably higher than that of the small-size steam turbine and reciprocating engine. There has not been a like improvement in the efficiency, nor a comparable reduction in cost, of the small reciprocating steam unit, and a natural result has been the expansion of central stations. As bearing on the water-power situation, obviously many sites which 15 years ago might have been developed to sell energy in successful competition with steam at its then cost could not now be so developed, and in consequence their development is no longer commercially possible. The cost of producing power from either water or steam is a function of load. Fixed charges remain practically unchanged in both instances, whether the output in energy be large or small, but with a steam plant, increased output means increased fuel consumption, while a water plant operates, either with or without load, with but little variation in expense. To illustrate by a concrete example representing not unusual conditions, suppose we assume a steam plant using 2½ lb. of coal per kilowatt hour at a price of $3.00 per short ton, and having a plant or output factor of 35%—that is to say, an output equal to 35% of its theoretical output if every unit were loaded to capacity 24 hours each day of the year. Under these assumptions, the cost of fuel per unit of installed capacity per year would be $11.50, and if the other operating and maintenance charges be assumed to offset fairly those of a water installation of equivalent size, $11.50 represents the additional fixed charges which the hydro-electric plant could carry and produce power at an equal cost. If the fixed charges (interest, taxes, insurance, and amortization) total 11½%, therefore, the hydro-electric investment per kilowatt capacity could exceed that of steam by $100. This is not an abnormal excess. Many hydro-electric developments exceed the cost of equivalent steam-driven systems by much greater amounts, in which cases they become commercial projects only if either coal be more expensive per unit of output, or the plant factor be higher, or some other operating or maintenance conditions be more favorable. Further, as has been previously stated, hydro-electric power is inferior to steam-electric power. The reasons are elementary. Stream flow is subject to seasonal variation, and therefore to complete or partial interruption by drought in summer and by ice in winter. Floods are a menace. Long transmission lines may break, from wind or sleet, or the service be disarranged by lightning. The losses on such lines vary with load, and are frequently responsible for annoying pressure variations. On account of these and other reasons, hydro-electric power cannot prevail against steam competition at the same or a slightly lower price. It must be materially lower.

"We do not mean to imply that water power may not be a commercially practicable competitor of steam. Many successful hydro-electric installations give substantial proof to the contrary. We do wish most emphatically to combat, however, the widely held but mistaken view that any water-driven plant will produce power at lower cost than steam can, and that the margin is so large that investors generally are eagerly seeking a chance to put money into hydro-electric projects. The most careful investigation, frequently demanding substantial expenditure and the keenest scrutiny by experts, is needed to discriminate between worthy and commercially impracticable projects, and the difference is often so small that the imposition of even what seem to be minor burdens is sufficient to turn the scale in favor of steam and entirely prevent what might otherwise be a desirable hydro-electric development.

"The second condition which vitally affects development is statutory. After 10 years or more of discussion it has come to be generally agreed that our Federal laws discourage the development of a large proportion of the Nation's water powers, and remedial legislation has been considered at every session of Congress for many years. The legal obstacles are quite distinct and separate from the economic facts which have been previously described, and are in addition thereto.

"Of the estimated 55 000 000 undeveloped water horse-power in the entire country, approximately 40 000 000 is located within the boundaries of the thirteen so-called Western water-power States. In these same States the Federal Government still retains as proprietor 760 000 000 acres, or more than two-thirds of the aggregate acreage of all these States taken together. In order to develop power in that section, it is, therefore, nearly always necessary to use some part of this public domain, if not for the dam site itself, at least for flowage, for transmission right of way, or for some other purpose. Existing law forbids such use except under permit issued by the Secretary of the Interior, and revocable without cause, at any time, by himself or his successor in office. It was once believed that revocation would only follow gross abuse, well established by evidence, but the drastic action of a one-time Secretary of the Interior, some years ago, to the contrary, disabused investors of this confidence, and demonstrated by a sad object lesson the insecure tenure afforded by existing law. As funds for hydro-electric development must come from private sources, the unstable tenure imposed by this condition has constituted so great a hazard of loss that the private investor has been loath to assume it. The unfortunate—almost disastrous—result has been practical stagnation in water-power development for many years. Many available power sites, not in the Western States, or not on the public domain, are on navigable streams. For each such project a special Act of Congress is necessary. The difficulty of obtaining suitable rights by this means has been found so very great as largely to discourage, even if not entirely to prevent, the developments affected. The several remedial laws recently considered by Congress recognize the essential facts, and agree that the remedy is a new law containing the following provisions, namely: An indeterminate permit, irrevocable during 50 years, except for cause judicially determined, and continuing thereafter unless and until the Federal Government either renews its permit on mutually agreeable terms, or for itself or through a new permittee, takes over, at its fair value, the hydraulic works and certain other parts of the development. The various proposed laws differ as to what parts of the development may be taken; as to whether or not rentals shall be paid, and their basis, and in many other particulars. Engineering Council does not consider itself expert in legal matters, and will not undertake to discuss the relative merits of the different plans. It should be pointed out, however, that an hydro-electric enterprise, being once successfully established, it is alike to the interest of the owners, of the Government, and of the public, that it should continue indefinitely without interruption. There is no economic reason to be served by a cessation, and the only reasons for providing a legal means of recapturing the installation and the water rights are, first, to preserve an additional measure of Government control against possible abuse by the permittee, and, second, against a remote contingency which might make it desirable that the Government would want to use the power for some other purpose. A successful power enterprise at the end of 50 years will have multiplied the capacity of its initial installation many times, variously estimated at from five to twenty. In doing so, it is almost certain that, not only will the entire power available at the original site be fully developed, but other powers as well, which latter may or may not be dependent upon Government permits. Still further, in nearly all cases, steam plants as well as water plants are necessary. These steam plants are necessary to supplement hydro-electric power at period of low water and in case of interruption, as well as, in some instances, to provide increased capacity. In fact, modern practice is rapidly approaching that of providing steam capacity equal to 100% of hydro-electric for the purposes stated. In any event, the growth of the enterprise over a term of years will be continuous and progressive. There will never come a time when it may be said to have been completed and subject to no further expansion. This continuing growth makes burdensome and usually abortive any attempt to amortize the investment, while the investment in other water powers or in steam plants or both, interconnected with, and generally dependent for their economic operation on, the original development, renders the right to recapture that development only very onerous, and one which constitutes a serious impediment to the free and full development of an enterprise which is otherwise most desirable from all standpoints. With respect to power sites on the public domain and on navigable streams, the Government is in the position of seeking to have its resources developed without assuming any business hazard and without contributing either capital or credit. It would be unfortunate, in the light of past experience, if any new laws which may be enacted should put the Government in the position of bargaining with capital and of offering just sufficient incentive not to induce capital to undertake the developments desired, thereby, while apparently providing a remedy, in reality insuring a continuance of the present undesirable condition. Hydro-electric enterprises must compete with the demands of other industries for capital. Experience has shown that, even without the imposition of additional financial burdens, many of them are not sufficiently attractive to secure development, and, as the attractive prospects grade by imperceptible degrees into the unattractive ones, it is perhaps self-evident that every additional burden, however small, transfers a percentage of such projects from commercial into uncommercial prospects. It is our belief that the benefits afforded the communities served by cheap power, and to the Nation by the conservation of coal resulting from the substitution of a self-renewing for a non-renewable natural resource, are far more valuable than is the exact solution of the question of restricting the returns to capital to their irreducible minimum point. The present emergency, due to the progress of the war, has forcibly illustrated the importance of having developed the greatest possible number of water powers as a source of industrial power supply. As it consumes no fuel, the substitution of water for steam power would release to other uses all the extensive railroad and water facilities now engaged in transporting coal. It would similarly release a corresponding volume of labor now occupied in mining this coal and in operating such transportation agencies as well, and the boiler-room forces of the steam-power plants themselves."

Engineers in Government Service.

Engineering Council, through its American Engineering Service Committee, has, during the past few months, supplied to various Government departments and bureaus, in response to their requests, several thousand names of engineers from which men were to be selected to fill a great variety of positions in uniformed and civilian service for Army and Navy and other branches of the Government's activities in connection with the war, as well as for indirect service for manufacturers and contractors engaged upon Government war work.

To meet these demands, the American Engineering Service Committee has assembled, in its offices in the Engineering Societies Building, New York, extensive lists and much detailed information concerning engineers in all branches of the profession throughout the length and breadth of the land. It will readily be appreciated that, if these lists are to be maintained in the most useful condition to the Government and to Engineering Council, the committee should receive promptly information concerning each engineer who has gone into any kind of Government service, direct or indirect, so that a record may be made on his cards in the committee's office.

Engineers reading these lines, to whom this request applies, are urged to send at once their names, present addresses, and occupations in the Government service, with brief statement as to whether or not they are available for other service, to American Engineering Service Committee, Room 901, 29 West 39th Street, New York. Other readers are asked to bring this request to the attention of such engineers or to send information directly to the committee.

ANNOUNCEMENTS

The Reading Room of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

March 6th, 1918.—8.30 P. M.—A regular business meeting will be held, and a paper by Floyd A. Nagler, Jun. Am. Soc. C. E., entitled "Verification of the Bazin Weir Formula by Hydro-Chemical Gaugings", will be presented for discussion.

This paper was printed in *Proceedings* for January, 1918.

March 20th, 1918.—8.30 P. M.—At this meeting a paper by W. C. Hammatt, M. Am. Soc. C. E., entitled "Determination of the Duty of Water by Analytical Experiment", will be presented for discussion.

This paper is printed in this number of *Proceedings.*

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that if it were generally known to engineers that such assistance could be had, many would avail themselves of it.

On October 1st, 1916, the Library of the American Society of Civil Engineers ceased to exist as such, and was merged in the Engineering Societies Library, adding 67 000 volumes to the collection which comprises also the former libraries of the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, and now has a total of 133 000 volumes and pamphlets. Containing, as the Library now does, the special collections mentioned, its scope is broadened, and, as it receives an unusually large number of technical periodicals, it is well equipped to continue the service formerly rendered by the Society Library.

The Engineering Societies Library offers this service at a cost which is trifling compared with the value of the time of an engineer who personally looks up such matters, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

It sometimes happens that references are found which are not readily accessible to the person for whom the search is made. In that case the Library is prepared to furnish photographic copies of the material at a small price per page. This method is particularly useful when there are drawings or figures in the text, which would be very expensive to reproduce by hand.

The Library is also able to provide translations of articles in foreign languages when desired.

Requests for searches, copies, translations, etc., should be addressed to the Director, Engineering Societies Library, 29 West 39th Street, New York City, who will gladly give information concerning the charges for the various kinds of service.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings.*

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion will be published as heretofore in *Proceedings*, and set down for presentation to a future meeting of the Society, and on these oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which from their mathematical or technical nature, in the opinion of the Committee, are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions only will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions.*

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 35 of the Year Book for 1917.

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association, Organized 1905.

Jerome Newman, President; Nathan A. Bowers, Secretary-Treasurer, 502 Rialto Building, San Francisco, Cal.

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Palace Hotel, on the third Tuesday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at noon, every Wednesday, at the Engineers' Club, 57 Post Street, where special tables are reserved for members and guests of the Association.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

(Abstract of Minutes of Meeting)

December 18th, 1917.—The Thirteenth Annual Meeting was called to order.

Ten-minute talks on "Why Engineers Have Not Achieved a Higher Rank Among the Professions", were presented by Messrs. C. D. Marx, A. H. Markwart, R. S. Chew, E. J. Schneider, C. J. Rhodin, and H. D. Dewell, and a committee consisting of Messrs. Bowers, Dewell, and Rhodin, was appointed to compile these addresses for publication and to report at the next meeting.

The following officers for 1918 were elected: President, Jerome Newman; Second Vice-President, W. C. Hammatt; and Secretary-Treasurer, Nathan A. Bowers.

Adjourned.

Colorado Association, Organized 1908.

Robert Follansbee, President; L. R. Hinman, Secretary-Treasurer, 1400 West Colfax Avenue, Denver, Colo.

The meetings of the Colorado Association of Members of the American Society of Civil Engineers (Denver, Colo.) are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesdays at 12.30 P. M., at Daniel's and Fisher's.

Visiting members are urged to attend the meetings and luncheons.

Atlanta Association, Organized 1912.

B. M. Hall, President; W. C. Spiker, Secretary-Treasurer, 1408 Candler Building, Atlanta, Ga.

Baltimore Association, Organized 1914.

Mason D. Pratt, President; Charles J. Tilden, Secretary-Treasurer, The Johns Hopkins University, Baltimore, Md.

Cleveland Association, Organized 1914.

Harry Fuller, President; George H. Tinker, Secretary-Treasurer, 516 Columbia Building, Cleveland, Ohio.

(Abstract of Minutes of Meeting)

January 5th, 1918.—The meeting was called to order at 12.30 P. M., at the rooms of the Cleveland Engineering Society; President Watson in the chair; George H. Tinker, Secretary; and present, also, 25 members.

The minutes of the meeting of June 30th, 1917, were read and approved.

On motion duly seconded, Messrs. J. R. Poe, W. P. Brown, and J. C. Spencer were appointed a Nominating Committee to select candidates for officers for 1918, which Committee, after consultation, presented the following names: for President, Harry Fuller; Vice-President, A. J. Himes; and Secretary-Treasurer, George H. Tinker.

On motion, duly seconded, these candidates were declared unanimously elected.

The Secretary read a report from the Committee on Military Highways and also a letter from Director J. V. Davies authorizing the discontinuance of that work. On motion, duly seconded, the report was accepted and ordered filed, and the Committee was discharged with thanks.

The resolution of the Executive Committee of the Board of Direction of the Society relative to the War Revenue Act of 1917, was read, and the subject was discussed by Messrs. Leffler, Ellms, Ritchie, Spencer, and F. C. Osborn.

On motion, duly seconded, the resolution was approved as the action of the Association, and copies were ordered sent to the Senators and Representatives in Congress from Ohio.

On motion, duly seconded, it was also decided to instruct the Legislative Committee to confer with other professional bodies requesting similar action.

A letter from H. R. Buck, M. Am. Soc. C. E., relative to Student Membership was read and discussed by Messrs. Leffler and Himes.

The Secretary announced the formation of the Pittsburgh Association of Members of the American Society of Civil Engineers and a suitable division of territory, the Pittsburgh Association to look after the interests of members in Pennsylvania and West Virginia and this Association of those in Ohio.

The proposed amendments to the Constitution of the Society were discussed by Messrs. Ritchie, Osborn, Leffler, Thomas, Poe, and Himes. On motion, duly seconded, it was the sense of the meeting, 25 members being present, that, as a matter of principle, the Secretary should not be a member of the Board of Direction.

The Secretary announced the purchase of a Service Flag with eight stars.

Adjourned.

Detroit Association, Organized 1916.

T. A. Leisen, President; Clarence W. Hubbell, Secretary, 2348 Penobscot Building, Detroit, Mich.

The regular meetings of the Association are held on the second Friday of December, April, and October, the last being the Annual Meeting.

District of Columbia Association, Organized 1916.

A. P. Davis, President; John C. Hoyt, Secretary-Treasurer, U. S. Geological Survey, Washington, D. C.

(Abstract of Minutes of Meeting)

December 29th, 1917.—The meeting was called to order; President Davis in the chair; John C. Hoyt, Secretary; and present, also, 21 members.

The following officers were elected for the ensuing year: President, Arthur P. Davis; Vice-President, D. S. Carll; and Secretary-Treasurer, John C. Hoyt.

The proposed revision of the Constitution of the Society was considered, and the following amendments were suggested:

Article II, Section 2, amend final clause to read: "shall have had responsible charge of engineering work of high grade for at least five years, and shall be qualified to design work of such character."

Article II, Section 4, amend final sentence to read: "The performance of the duties of a Professor of Engineering in such a school shall sidered, and the following amendments were suggested:
of engineering work."

On motion, duly seconded, Mr. John S. Conway was directed to present these amendments in behalf of the Association at the Annual Meeting of the Society, on January 16th, 1918.

Adjourned.

Duluth Association, Organized 1917.

F. E. House, President; Walter G. Zimmermann, Secretary, Wolvin Building, Duluth, Minn.

The regular meetings of the Association are held at noon on the third Monday of each month (usually at the Kitchi Gamma Club), with luncheon, followed by a short business session and the reading of papers. Visiting members of the American Society of Civil Engineers can secure from the Secretary definite information relating to the meetings, at which they will be welcomed. The Annual Meeting is held on the third Monday in May.

(Abstract of Minutes of Meeting)

January 21st, 1918.—The meeting was called to order; President F. E. House in the chair; Walter G. Zimmermann, Secretary; and present, also, 20 members and 3 guests.

To conform to the spirit of the heatless Monday regulations, it was decided to hold the February and March meetings of the Association on the third Tuesdays instead of the third Mondays.

Mr. W. H. Hoyt addressed the meeting on the plans for entertaining at the Annual Convention of the Minnesota Surveyors and Engineers Society to be held on February 21st-23d, 1918, in Duluth, and asked for the co-operation and attendance of the members of the Association at the Convention.

The Committee on Publication of the papers read before the Association was directed to publish the 1917 papers and assess the members for the expense.

A paper by Major T. F. McGilvray, of the United States Engineer Officers Reserve Corps, on "The Properties of Sandstone Concrete", was read by Mr. E. R. Lewis, and it was decided that a discussion of the paper, led by Mr. Clarence Coleman, should be the feature of the February meeting.

Adjourned.

Illinois Association, Organized 1916.

A. S. Baldwin, President; Edgar S. Nethercut, Secretary-Treasurer, 705 Michigan Ave., Evanston, Ill.

The regular meetings of the Association are held on the second Monday of March, June, September, and December, the last being the Annual Meeting. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary.

Louisiana Association, Organized 1914.

W. B. Gregory, President; Charles W. Okey, Secretary, Tulane University, New Orleans, La.

The regular meetings of the Association are held at The Cabildo, New Orleans, La., on the first Monday of January, April, July, and October.

Nebraska Association, Organized 1917.

George L. Campen, President; Homer V. Knouse, Secretary-Treasurer, 115 City Hall, Omaha, Nebr.

Regular meetings of the Association are held on the first Saturday of each month, except July and August, and at such places as may be appointed from time to time by the Executive Committee. The Annual Meeting is held in Lincoln, Nebr., on the second Friday in January.

An "Engineers' Round Table" is reserved daily for luncheon, at Courtenay's Restaurant, 17th and Douglas Streets, Omaha, to which all engineers are invited. Visiting members of the Society are especially urged to communicate with the Secretary when in the city.

(Abstract of Minutes of Meeting)

January 11th, 1918.—A joint meeting of the Nebraska Society of Engineers, the Lincoln Engineers Club, and the Association, was held at Lincoln, Nebr., at which addresses were presented as follows: "Military Engineering", by Clark E. Mickey, Assoc. M. Am. Soc. C. E.; "Concentrated Loads on Highway Bridges", by Milo S. Ketchum, M. Am. Soc. C. E.; and "Reorganization of the Lincoln Telegraph and Telephone Company Due to the War", by M. T. Caster, President of the Lincoln Engineers Club. The meeting was also addressed briefly by Mr. Soltan, President of the University Engineering Society, and by Col. H. L. Roberts, U. S. A. (*Retired*).

The Annual Meeting of the Association was called to order at 10.15 P. M.; President Darrow in the chair; Homer V. Knouse, Secretary; and present, also, 8 members and 1 guest.

The minutes of the meeting of December 8th, 1917, were read and approved.

The Secretary called attention to a deficit for 1917 and suggested that the dues of the members be increased to cover the probable increase in expenses of the Association during the coming year.

On motion, duly seconded, it was decided that a special assessment of 50 cents be levied on the members to cover the 1917 deficit and to assist in paying the dues of members in the Government service.

On motion, duly seconded, it was also decided to levy a special assessment of $1.00 to cover the extra expenses for 1918.

Messrs. Grant and Arend were appointed Tellers to canvass the ballots for Officers for 1918, and, on the presentation of their report, President Darrow announced the following elections: President, George L. Campen; Senior Vice-President, H. A. Holdrege; Junior Vice-President, John A. Bruce; and Secretary, Homer V. Knouse.

Matters relative to the Parent Society were discussed, and Dean Ketchum was requested to represent the Association in urging the adoption of an amendment authorizing the foundation of Student Branches.

Adjourned.

Northwestern Association, Organized 1914.

P. E. Thian, President; Ralph D. Thomas, Secretary, 508 South First Street, Minneapolis, Minn.

The meetings of the Association are held bi-monthly, alternating between St. Paul and Minneapolis, on the third Friday of each month. Information as to the time and place of such meetings will be furnished on application to the Secretary.

Philadelphia Association, Organized 1913.

Henry H. Quimby, President; C. W. Thorn, Secretary, 1313 South Broad Street, Philadelphia, Pa.

The regular meetings of the Association are held at the Engineers' Club of Philadelphia, 1317 Spruce Street, on the First Monday in January, April, and October, the last being the Annual Meeting.

Pittsburgh Association, Organized 1917.

Richard Khuen, Jr., President; Charles M. Reppert, Secretary-Treasurer, 422 City-County Building, Pittsburgh, Pa.

The Annual Meeting of the Association is held on the first Monday in October. The time and place of other meetings are not fixed, but this information will be furnished on application to the Secretary.

Portland, Ore., Association, Organized 1913.

G. B. Hegardt, President; C. P. Keyser, Secretary, 1147 East Yamhill Street, Portland, Ore.

(Abstract of Minutes of Meeting)

January 11th, 1918.—The Annual Meeting was called to order.

The following officers were elected: President, G. B. Hegardt; First Vice-President, H. A. Rands; Second Vice-President, W. G. Brown; Treasurer, Orrin E. Stanley; and Secretary, C. P. Keyser.

The office of Honorary President was established, and Mr. D. D. Clarke was elected thereto by acclamation, as a mark of the Association's appreciation of his zeal and achievement as a member of the Society during the past 35 years.

The resolution of the Executive Committee of the Board of Direction of the Society, relative to the War Revenue Act of 1917, was presented, and it was decided to address communications to the Oregon Senators and Representatives as suggested and that individual members of the Association should use their personal influence to get the clause affecting engineers and professional men appealed or amended.

Adjourned.

St. Louis Association, Organized 1888 (Constitution Approved by Board, 1914).

J. A. Ockerson, President; C. M. Daily, Secretary-Treasurer, 34 East Grand Avenue, St. Louis, Mo.

The Annual Meeting of the Association for the election of officers and for the transaction of business, is held on the fourth Monday in November. Two meetings each year, for the presentation and discussion of technical papers, are held in the Auditorium of the Engineers Club of St. Louis and are open to members of the Associated Societies. Other "get-together" meetings are held regularly for dinner or luncheon on the fourth Monday of each month except July, August, and November.

San Diego Association, Organized 1915.

N. B. Kellogg, President; J. R. Comly, Secretary-Treasurer, 4105 Falcon Street, San Diego, Cal.

Seattle Association, Organized 1913.

Joseph Jacobs, President; Carl H. Reeves, Secretary-Treasurer, 444 Henry Building, Seattle, Wash.

The regular meetings of the Association are held at 12.15 P. M., on the last Monday of each month, at The Frye Hotel.

Southern California Association, Organized 1914.

H. Hawgood, President; H. W. Dennis, Secretary, 329 San Fernando Building, Los Angeles, Cal.

The Southern California Association of Members of the American Society of Civil Engineers (Los Angeles, Cal.) holds regular bimonthly meetings with banquet, at Hotel Clark, on the second Wednesday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M. every Wednesday, and the place of meeting may be ascertained from the Secretary.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in Los Angeles, and any such member will be gladly welcomed as a guest at any of the meetings or luncheons.

Spokane Association, Organized 1914.

J. C. Ralston, President; B. J. Garnett, Secretary, City Hall, Spokane, Wash.

The regular meetings of the Association are held on the second Friday of each month, except July and August. The hour and place

of meeting are not fixed, but this information will be furnished on application to the Secretary

Visiting members are invited to attend the meetings and luncheons.

Texas Association, Organized 1913.

John B. Hawley, President; J. F. Witt, Secretary, Dallas, Tex.

Utah Association, Organized 1916.

George L. Swendsen, President; H. S. Kleinschmidt, Secretary-Treasurer, 306 Dooly Building, Salt Lake City, Utah.

The Annual Meeting of the Association is held on the first Wednesday in April. The time of other meetings is not fixed, but this information will be furnished on application to the Secretary.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms, and at all meetings:

American Institute of Electrical Engineers, 25 West Thirty-ninth Street, New York City.

American Institute of Mining Engineers, 25 West Thirty-ninth Street, New York City.

American Society of Mechanical Engineers, 25 West Thirty-ninth Street, New York City.

Assoçiacão dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 176 Mansfield Street, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, Public Library, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Detroit Engineering Society, 46 Grand River Avenue, West, Detroit, Mich.

Engineering Association of Nashville, Commercial Club Building, Nashville, Tenn.

Engineering Association of New South Wales, 5 Elizabeth Street, Sydney, New South Wales, Australia.

Engineering Societies Club of Hawaii, E. F. Cykler, Secretary, Honolulu, Hawaii.

Engineers and Architects Club of Louisville, 1412 Starks Building, Louisville, Ky.

Engineers' Club of Baltimore, 6 West Eager Street, Baltimore, Md.

Engineers' Club of Kansas City, Robert S. Beard, Secretary, Third Floor, City Hall, Kansas City, Mo.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Club of Trenton, Trent Theatre Building, 12 North Warren Street, Trenton, N. J.

Engineers' Society of Northeastern Pennsylvania, 415 Washington Avenue, Scranton, Pa.

Engineers' Society of Pennsylvania, 31 South Front Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 568 Union Arcade Building, Pittsburgh, Pa.

Florida Engineering Society, J. R. Benton, Secretary, Gainesville, Fla.

Institute of Marine Engineers, The Minories, Tower Hill, London, E., England.

Institution of Civil Engineers, Great George Street, Westminster, S. W., London, England.

Institution of Engineers of the River Plate, Calle 25 de Mayo 195, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Koninlijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, State Museum Building, Chartres and St. Ann Streets, New Orleans, La.

Memphis Engineers' Club, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Montana Society of Engineers, Butte, Mont.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Oregon Society of Civil Engineers, Portland, Ore.

Pacific Northwest Society of Engineers, 803 Central Building, Seattle, Wash.

Rochester Engineering Society, Rochester, N. Y.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Societe des Ingenieurs Civils de France, 19 rue Blanche, Paris, France.

Society of Engineers, 17 Victoria Street, Westminster, S. W., London, England.

Southwestern Society of Engineers, C. E. Barglebaugh, Secretary, 703 First National Bank Building, El Paso, Tex.

Svenska Teknologforeningen, Brunkebergstorg 18, Stockholm, Sweden.

Tekniske Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Vermont Society of Engineers, George A. Reed, Secretary, Montpelier, Vt.

Western Society of Engineers, 1735 Monadnock Block, Chicago, Ill.

ACCESSIONS TO THE UNITED ENGINEERING SOCIETY LIBRARY

(From January 1st to February 1st, 1918)

DONATIONS*

The statements made in these notices are taken from the books themselves, and this Society is not responsible for them.

INTERIOR WIRING:

And Systems for Electric Light and Power Service; a Manual of Practice for Electrical Workers, Contractors, Architects and Schools. By Arthur L. Cook. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 10 + 416 pp., 248 illus., 2 diagrams, 7 x 5 in., flexible cloth. $2.00.

There are many text-books, the author says, which deal with the principles of operation of electrical apparatus and the methods of calculating electrical circuits, but the usual electrical worker or student does not possess a sufficient background of practical experience to enable him to use these principles to design a wiring installation. In this book an attempt is made to supplement the text-books by giving information which will compensate, in part at least, for a lack of practical experience.

THEORY AND OPERATION OF DIRECT-CURRENT MACHINERY.

Prepared in the Extension Division of the University of Wisconsin. By Cyril M. Jansky. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 10 + 285 pp., 214 illus., 9 x 6 in., cloth. $2.50.

A text-book prepared by the Extension Division of the University of Wisconsin for students of limited mathematical training. An elementary course in the principles involved, their applications in construction, and the operation and care of the machines.

HYDRO-ELECTRIC POWER STATIONS.

By Eric A. Lof and David B. Rushmore. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 10 + 822 pp., 407 illus., 2 diagrams, 9 x 6 in., cloth. $6.00.

Treats of the hydraulic, electrical, and economic factors involved in the planning, construction, and operation of these plants, but does not deal with the design of the individual structures, machinery, and apparatus of which a power station is composed. The appendices give a bibliography of American hydro-electric stations and a table of the principal data on transmission systems operating at 70 000 volts or more. Contents: General Introduction; Hydrology; Classification of Developments; Dams and Headworks; Water Conductors and Accessories; Storage Reservoirs; Power-House Design; Hydraulic Equipment; Electrical Equipment; Economical Aspects; Organization and Operation; Appendix I, References to Descriptions of Plants; II, Principal Data on Transmission Systems Operating at 70 000 Volts and Above; III, Turbine Testing Code.

FUNDAMENTALS OF NAVAL SERVICE.

By Commander Yates Stirling. Special Chapters by Lt.-Commander H. C. Mustin, Lt.-Commander C. S. McDowell, and Dr. Ralph Walker McDowell. Phila. and Lond., J. B. Lippincott Co. (copyright 1917). 589 pp., 32 illus., 2 pl., 2 diagrams, 7 x 5 in., cloth. $2.00.

Epitomizes a variety of information, usually to be obtained only in many books, in the form of a manual for those interested in our navy, and who may choose to serve their country on the water.

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* Unless otherwise specified, books in this list have been donated by the publishers.

STEAM POWER PLANT ENGINEERING.

By George F. Gebhardt. 5th ed., rewritten and reset. N. Y., John Wiley and Sons, Inc.; Lond., Chapman and Hall, Ltd., 1917. 16 + 1057 pp., 642 illus., 1 diagram, 9 x 6 in., cloth. $4.00.

This edition follows the plan of the earlier ones, but has been greatly enlarged and entirely rewritten so as to include the modern developments of the steam power plant. Supplementary chapters on Elementary Thermodynamics, Properties of Steam, and Properties of Dry and Saturated Air, have been added.

FIRST REPORT TO THE COUNCIL OF THE NORTH EAST COAST INSTITUTION

Of Engineers and Shipbuilders on Certain Methods of Producing Vacuum. By Edwin L. Orde, C. Waldie Cairns and J. Morrow. Newcastle-upon-Tyne, North East Coast Institution of Engineers and Shipbuilders, 1916-17. 34 pp., 16 illus., 1 pl., tab., 12 x 9 in., paper. 10s. 6d.

Presents the results of a series of experiments on apparatus by which the air is withdrawn from the condenser by reciprocating air pumps and on that by which air is withdrawn from the condenser by fluid jets, by which it is compressed and delivered to the air pumps in a less rarefied state.

THE FLYER'S GUIDE;

An Elementary Handbook for Aviators. By Capt. N. J. Gill. N. Y., E. P. Dutton and Co., 1917. 153 pp., 18 illus., 3 pl., 9 x 6 in., cloth. $2.00.

Instructions to beginners on methods of flying, the construction and maintenance of air-planes, the theory of flight, internal combustion engines and ignition devices. Intended as a guide to those learning to fly, especially for military pilots.

THE EYES OF THE ARMY AND NAVY:

Practical Aviation. By Albert H. Munday. N. Y., & Lond., Harper & Bros. (copyright 1917). 226 pp., 49 illus., 4 pl., 7 x 5 in., cloth. $1.50.

A handbook intended for the layman with a moderate education who wishes to obtain a practical knowledge of flying and the fundamental principles of air-plane construction, engines, etc. Based on the writer's experience in the Royal Naval Air Service, as an aeroplane pilot.

SPHERICAL BALLOONING;

Some of the Requirements. By P. J. McCullough. St. Louis, The Mangan Printing Co. (copyright 1917). 46 pp., 11 illus., 9 x 6 in., paper. $1.00.

This monograph explains clearly and concisely the proper procedure in assembling and piloting spherical balloons. Intended as a primary text for beginners.

TEXT-BOOK OF ORDNANCE AND GUNNERY.

By Lt.-Col. William H. Tschappat. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 10 + 705 pp., 314 illus., 1 diagram, 9 x 6 in., cloth. $6.50.

A text-book for the senior class at the U. S. Military Academy. Founded on Lissak's "Ordnance and Gunnery", with revisions and new material.

PRACTICAL INSTRUCTIONS

In the Search for, and the Determination of, the Useful Minerals, Including the Rare Ores; For the Prospector, Miner, and as a Ready Reference for Everybody Interested in the Mineral Industry. By Alexander McLeod. 2d ed., enl. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 27 + 254 pp., 7 x 4 in., flexible cloth. $1.75.

This pocketbook of prospecting and testing includes simple tests which require no skill and only apparatus and chemicals which are easily obtainable. The second edition contains various additions and corrections, increasing it to three times the length of the first.

THE FOUNDATIONS OF NATIONAL PROSPERITY;

Studies in the Conservation of Permanent National Resources. By Richard T. Ely, Ralph H. Hess, Charles K. Leith, and Thomas Nixon Carver. N. Y., The Macmillan Co., 1917. 29 + 378 pp., 8 x 5 in., cloth. $2.00.

The title-page of this work emphasizes the thought that conservation is to be regarded as a treatment of the foundations of national prosperity. It deals with the permanent causes of the Wealth of Nations. The titanic war struggle in which we are engaged makes it important to emphasize the fact that in the treatment of conservation we are dealing with national preparedness both for war and peace. There is danger that in dealing with measures of preparedness we may direct our attention too exclusively to the needs of to-day and to-morrow, whereas nothing stands out more clearly as a result of our world war than the fact that preparedness must be a permanent, all-round condition; for otherwise our preparations may be in vain. Although it is true that this book deals mainly with permanent conditions of prosperity and preparedness, it also has lessons for the immediate present. Contents: Conservation and Economic Theory; Conservation and Economic Evolution; Conservation of Certain Mineral Resources; Conservation of Human Resources.

APPLIED MOTION STUDY:

A Collection of Papers on the Efficient Method to Industrial Preparedness. By Frank B. Gilbreth and L. M. Gilbreth. N. Y., Sturgis and Walton Co., 1917. 18 + 220 pp., 7 pl., 1 diagram, 8 x 5 in., cloth. $1.50.

In these articles which are here reprinted from various periodicals, the authors describe motion study as applied to various fields of activity, and outline its principles and practice so as to make possible its application in any and all lines of work. Contents: What Scientific Management Means to America's Industrial Position; Units, Methods, and Devices of Measurement under Scientific Management; Motion Study as an Industrial Opportunity; Motion Study and Time Study Instruments of Precision; Chronocyclegraph Motion Devices for Measuring Achievement; Motion Models: Their Use in the Transference of Experience and the Presentation of Comparative Results in Educational Methods; Motion Study for the Crippled Soldier; The Practice of Scientific Management; The Three Position Plan of Promotion; The Effect of Motion Study upon the Workers.

THE MICROSCOPE;

An Introduction to Microscopic Methods and to Histology. By Simon Henry Gage. 12 ed., rewritten. Ithaca, The Comstock Publishing Co., 1917. 9 + 472 pp., 253 illus., 9 x 6 in., cloth. $3.00.

This edition, the author states, has been more thoroughly revised than any of its predecessors, and includes those new developments in processes and apparatus that he has found helpful by personal tests. Micro-chemistry and metallography have been omitted from this edition as adequate special text-books on these subjects are now available.

BIOCHEMICAL CATALYSTS IN LIFE AND INDUSTRY;

Proteolytic Enzymes. By Jean Effront. Translated by Samuel C. Prescott, Assisted by Charles S. Venable. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 11 + 752 pp., 9 x 6 in., cloth. $5.00.

A companion volume to the author's "Enzymes and Their Applications", limited to the proteolytic enzymes, or those which act as catalysts for nitrogenous substances. Presents our knowledge of the action of these substances and of their products and describes the application of enzymes to industry. Bibliographies accompany each chapter.

EVERYMAN'S CHEMISTRY;

The Chemist's Point of View and His Recent Work Told for the Layman. By Ellwood Hendrick. N. Y. and Lond., Harper Bros. (copyright 1917). 374 pp., 8 x 5 in., cloth. $2.00.

The author has attempted to produce a readable, easily understood account of modern chemistry, with special stress on its application in actual life, for the use of those without special chemical training. Particular attention is given to industrial chemistry and to the most recent developments of American chemical industry.

SOIL CONDITIONS AND PLANT GROWTH.

By Edward J. Russell. 3d ed. N. Y. and Lond., Longmans, Green and Co., 1917. 243 pp., 14 illus., 10 x 6 in., boards. $2.00.

This volume, which belongs to the series of "Monographs on Biochemistry" edited by R. H. A. Plimmer and F. G. Hopkins, is an attempt to give a concise account of our present knowledge of the soil as a medium for plant life. The third edition has been considerably altered throughout, to include recent progress, and a new chapter discussing the colloidal properties of the soil has been added. An extensive select bibliography is given.

AN INTRODUCTION TO THE STUDY OF LANDSCAPE DESIGN.

By Henry Vincent Hubbard and Theodora Kimball. N. Y., The Macmillan Co., 1917. 20 + 406 pp., 40 illus., 36 pl., 11 x 9 in., cloth. $6.00.

Written, the authors state, to present a general conception of landscape design which may enable a designer better to determine for himself the relations of the objects and ideas with which he is dealing and better to prepare and use in a decisive way, in the individual problems of his profession, the natural aptitudes and acquired knowledge which are the tools of his trade. Contains numerous foot-note references and a select bibliography.

THE KILN DRYING OF LUMBER:

A Practical and Theoretical Treatise. By Harry Donald Tiemann. Phila. and Lond., J. B. Lippincott Co. (copyright 1917). 9 + 316 pp., 54 illus., 1 diagram, 9 x 6 in., cloth. $4.00.

The author, who is in charge of the kiln-drying experiments of the U. S. Forest Service, describes the structure and properties of wood, the common practices in drying; how wood dries; the principles and methods of kiln drying; the effect of various methods of drying upon the strength of wood, etc. Intended to provide the best available information in systematic form.

STREET RAILWAY ACCOUNTING:

A Manual of Operating Practice for Electric Railways. By Irville Augustus May. N. Y., The Ronald Press Co., 1917. 20 + 454 pp., 212 illus., 9 x 6 in., ½ mor. $5.00.

An outline of the working methods developed and actually used by the accounting departments of certain large companies which are operated in accordance with the regulations of the Interstate Commerce Commission as given in its "System of Uniform Accounts for Electric Railways". The author is Vice-President of the American Electric Railway Accountants Association.

PRACTICAL STREET CONSTRUCTION;

Planning Streets and Designing and Constructing the Details of Street Surface, Subsurface and Supersurface Structures. By A. Prescott Folwell. Reprinted from a Series of Articles Which Appeared in *Municipal Journal* during 1916. N. Y., Municipal Journal and Engineer, 1916. 248 pp., 151 illus., 9 x 6 in., cloth. $2.00.

A discussion of street alignment, grade, and cross-section, the location of underground constructions and their surface appurtenances, and the other features of city streets, especially prepared for the use of city engineers. Contents: What Streets are Used for; Planning Street Alignments; Diagonal Thoroughfares; Planning Thoroughfares; Street Planning in Newark; Street Widths; Sidewalk Widths; Minor Residence Streets; Local and Elastic Streets; Philadelphia Elastic Streets; Street Cross-Section; Motor Tracks and Street Grades; Street Grades; Planning Grades; Grade at Intersection; Intersected Grades; Gutters; Sidewalks and Sidewalk Construction; Sidewalk Obstructions.

GENERAL ELECTRIC COMPANY'S MEDICAL SERVICE AND HOSPITAL.

Schenectady, N. Y., General Electric Co. Illus., 11 x 9 in., cloth binder.

A brief account of the methods by which this company cares for the health of its employes, accompanied by a collection of safety bulletins used throughout its plants for educating its workmen in the prevention of accidents.

LIGHTHOUSES AND LIGHTSHIPS OF THE UNITED STATES.

By George R. Putnam. N. Y. and Bost., Houghton, Mifflin Co.; Cambridge, The Riverside Press, 1917. 13 + 308 pp., 36 pl., 9 x 6 in., cloth. $2.00.

This is a record of lighthouse work in this country, and of the main facts as to the lighthouses of the world, together with some account of personal deeds of the light-keepers. The book is planned to give a general and non-technical description of lighthouses, especially of those in the United States, and a history of their development.

ROLL OF HONOR

A List of Members of the Society Who are Serving in the Army or Navy of the United States or Any of Its Allies.*

Abbot, Frederic V. Brig.-Gen., Corps of Engrs., N. A., Office, Chief of Engrs., U. S. A., Washington, D. C.

Abbott, Frederick William. Lt.-Col., British Army; Metropolitan Club, New York City.

Acher, A. H. Maj., Corps of Engrs., U. S. A.; Dist. Engr., Box 1809, Seattle, Wash.

Ackerman, Alexander S. 1st Lieut., Engr. R. C., 11 Francis St., Newport, R. I.

Ackerman, Arthur P. 1st Lieut.,, Engr. R. C., 33d Engrs.; Great Barrington, Mass.

Adams, Edward M. Maj., U. S. A., Care, The Adjutant-Gen., U. S. A., Washington, D. C.

Adams, Milton Jewell. Capt., Co. C, 114th Engrs., Camp Beauregard, Alexandria, La.

Adams, Raymond E. Capt., Q. M. R. C.; Asst. to the Q. M., S. E. D., Peoples Bldg., Charleston, S. C.

Albert, Frederick W. Maj., Engr. R. C., 33d Engrs.; 23 Isham St., Burlington, Vt.

Alden, Herbert C. 1st Lieut., C. A. C., N. G. U. S., Fort Schuyler, New York City.

Alexander, E. Porter. 1st Lieut., Engr. R. C., 509th Engrs., Fort Sam Houston, San Antonio, Tex.

Alexander, Kay. Maj., 2d in Command, 12th Canadian Ry. Troops, B. E. F., France.

Allen, Franklin R. Capt., Engr. R. C., 8th Co., E. R. O. T. C., Camp Lee, Va.

Allen, Herschel Heathcote. 1st Lieut., Engr. R. C., Towson, Md.

Allen, Ralph B. 1st Lieut., Co. B, 25th Engrs., Am. Exp. Force.

Allen, Walter Henry. Maj., Engr. R. C.; 1112 East Jefferson St., Bloomington, Ill.

Allen, Walter Hinds. Civ. Engr., U. S. N. (rank of Lt.-Commander); Public Works Officer, Naval Training Station, Great Lakes, Ill.

Allison, William F. Maj., Engr. R. C., Am. Exp. Force, France.

Altman, Frank S. Lieut.,, Engr. R. C., 23d Engrs., Atchison, Kans.

Altstaetter, F. W. Col., Corps of Engrs., U. S. A., U. S. Engr. Office, Grand Rapids, Mich.

Anderson, J. E. Maj., 212th Field Co., Royal Engrs., B. E. F., France.

Anderson, J. H. 1st Lieut., Engr. R. C., 1st Co., Camp American University, Washington, D. C.

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* This list is made up from replies to a circular forwarded to members of the Society, and others, and is probably neither accurate nor complete. It is requested that the attention of the Secretary be called to any omissions or inaccuracies in order that they may be corrected in subsequent lists.

Anderson, W. P. Capt., Engr. R. C., 112th Engrs., Camp Sheridan, Ala.

Andrew, Clarence R. Capt., Engr. R. C., 23 Vernon Ave., Newport, R. I.

Andrews, Carl B. Capt., Engr. R. C. (*Unassigned*), 743 Wyllie St., Honolulu, Hawaii.

Andrews, J. H. M. Maj., Engr. R. C., 103d Engrs., Camp Hancock, Augusta, Ga.

Angas, Robert M. 1st Lieut., 106th Engrs., Camp Wheeler, Macon, Ga.

Applegarth, Gault. Capt., Engr. R. C., 23d Engrs., Care, War Dept., Washington, D. C.

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Wood, B. Russell. Capt., Engr. R. C., Care Depot Engr.'s Office, Terminal Bldg., Hoboken, N. J.

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Woodard, Wilkie. Capt., Co. H, 35th Engrs., Camp Grant, Rockford, Ill.

Woodle, Bernon Tisdale. Capt., 305th Engrs., Care, Depot Engr., Coca Cola Bldg., Baltimore, Md.

Woolworth, W. H. Capt., Engr. R. C., Headquarters, 2d Brigade, 1st Div., Am. Exp. Force, France.

Wright, John Bertram. Capt., Engr. R. C., P. O. Box 411, Oxford, Mass.

Wrightson, William D. Maj.; Chf. of San. Corps, Surgeon-General's Office, War Dept., Washington, D. C.

Yereance, Alex. W. 2d Lieut., Engr. R. C., Co. F, 305th Engrs., Camp Lee, Petersburg, Pa.

Yost, Howard McC. Capt., Engr. R. C., 2030 F St., N. W., Washington, D. C.

Young, Samuel M. Capt., Engr. R. C. (*Unassigned*), 635 Common St., New Orleans, La.

Zinn, George A. Col., Corps of Engrs., U. S. A., 321 Custom House, Portland, Ore.

MEMBERSHIP

(From January 4th to February 7th, 1918)

ADDITIONS

MEMBERS		Date of Membership.
Bellamy, Herbert Ernest. Officer in Chg., Flinders Naval Base, Crib Point, Victoria, Australia	Assoc. M. M.	Oct. 3, 1911 Oct. 9, 1917
Carr, Ossian Elmer. City Mgr., 558 Fifth St., Niagara Falls, N. Y.		Jan. 14, 1918
Cope, Erle Long. Cons. Engr., First National Bank Bldg., San Francisco, Cal.	Jun. Assoc. M. M.	Jan. 7, 1908 Dec. 6, 1910 Nov. 27, 1917
Knutson, George Henry. Civ. and Hydr. Engr. (Fargo Eng. Co.), 304 Commonwealth Bldg., Jackson, Mich.	Jun. Assoc. M. M.	Aug. 31, 1909 Mar. 14, 1916 Jan. 14, 1918
Lea, William Schurman. Cons. Engr. (R. S. & W. S. Lea), 809 New Birks Bldg., Montreal, Que., Canada.		Jan. 14, 1918
Mercier, Paul Emile. Chf. Engr. and City Surv., City Hall, Montreal, Que., Canada.		Nov. 27, 1917
Rusch, Henri. Chf. Engr., Bldg. Dept., City of St. Louis, 6038 Delmar Boulevard, St. Louis, Mo.	Assoc. M. M.	Nov. 8, 1909 Jan. 14, 1918
Shoecraft, Ezra Collin. City Engr., Flint, Mich.	Assoc. M. M.	Sept. 6, 1910 Jan. 14, 1918
Smith, Russell Biddle. Cons. and Superv. Engr., 50 East 42d St., New York City.	Assoc. M. M.	May 6, 1908 Jan. 14, 1918
Smulski, Edward. Cons. Engr. (S. M. I. Eng. Co.), 13 Park Row, New York City.	Assoc. M. M.	Feb. 4, 1913 Jan. 14, 1918
Terry, Alfred Howe. Penfield Rd., Fairfield, Conn.	Assoc. M. M.	June 6, 1906 Jan. 14, 1918
Trelease, Frank Johnson. Engr. in Executive Chg., Ford, Bacon & Davis, 921 Canal St., New Orleans, La.	Jun. Assoc. M. M.	May 3, 1910 April 2, 1913 Jan. 14, 1918
Viterbo, Lionel Rene. Pres., Reinforced Concrete Co. of St. Louis, 918 Wright Bldg., St. Louis, Mo.		Jan. 14, 1918

ASSOCIATE MEMBERS	
Alexander, Alexander. Estimator and Asst. to W. S. Hamell, 2160 Thirteenth St., Troy, N. Y.	Jan. 14, 1918
Almy, Edward Taber, Jr. Res. Engr., Sinclair Refining Co., Box 7, Packers Station, Kansas City, Kans.	Jan. 14, 1918
Bessey, Roy Frederic. With U. S. Navy Dept., Bureau of Yards and Docks, 1219 Shepherd St., N. W., Washington, D. C.	Jan. 14, 1918

ASSOCIATE MEMBERS (*Continued*)		Date of Membership.
BRANDT, RICHARD LUDWIG. Structural Engr., Alamo Iron Works, 226 Goliad St., San Antonio, Tex.		Jan. 14, 1918
BROWN, WILLIAM EDWARD. Chf. Draftsman, Dept. of Public Works, Box 173, Santo Domingo, Dominican Republic		Nov. 27, 1917
CARPENTER, JOHN SCHRODER. Chf. Draftsman, James Leffel & Co., Springfield, Ohio		Jan. 14, 1918
DREYFUS, SAMUEL CELLNER. Supt. of Constr. and Engr., R. M. Hudson Co., Camp Jackson, Columbia, S. C.	Jun. Assoc. M.	June 3, 1915 Jan. 14, 1918
DRURY, WILLIAM FISHER. Prin. Asst. Engr., Central Maine Power Co., 4 Greylock, Waterville, Me.	Jun. Assoc. M.	Mar. 4, 1913 Nov. 27, 1917
EDGAR, WILLIAM CLANEY. Erecting Engr., H. Koppers Co., Union Arcade, Pittsburgh, Pa.		Jan. 14, 1918
ESTES, LEWIS ALDEN. Sales Engr. and Mgr., Boston Office, Trussed Concrete Steel Co., 146 Summer St., Boston, Mass.	Jun. Assoc. M.	June 30, 1911 Jan. 14, 1918
FRISSELL, LAURENCE EMERSON. 506 South 8th Ave., Mount Vernon, N. Y.		Jan. 14, 1918
GALT, CHARLES ELIJAH. N. E. Cor. Gore and Swon Aves., Webster Groves, Mo.		Nov. 27, 1917
GAUTIER, RAOUL CHARLES RODOLPHE. Chf. Engr., Thompson & Binger, Inc., 280 Madison Ave., New York City.		Sept. 11, 1917
GIFFELS, WILLIAM CHARLES. 1st Lieut., Engrs., U. S. R., Co. A, 310th Engrs., Camp Custer, Battle Creek, Mich.	Jun. Assoc. M.	June 24, 1914 Sept. 11, 1917
HARTGERING, JOHN MCRAE. Associated with Clarence W. Hubbell, 2348 Penobscot Bldg., Detroit, Mich.		Jan. 14, 1918
HUMAN, THEODORE, JR. Engr. in Chg., Plantations and Constr., Atlantic Fruit Co., Cayo Mambi, Oriente, Cuba		Jan. 14, 1918
JACOBI, EMIL FREDERIC. Structural Engr., The Babcock & Wilcox Co., 109 Newman Ave., Bayonne, N. J.		Jan. 14, 1918
JOHNSON, FRANK MELVIN S. Capt., Corps of Engrs., U. S. A., 4th Div., 4th Engrs., Camp Greene, Charlotte, N. C.	Jun. Assoc. M.	Jan. 31, 1911 Jan. 14, 1918
KEMMERER, JOHN MARTIN. Co. 5, E. R. O. T. C., Camp Lee, Petersburg, Va.; 1222 East 53d St., Chicago, Ill.		Jan. 14, 1918
LA RUE, HARRY ANDERSON. Engr., Road Bureau, Portland Cement Assoc., 335 Rialto Bldg., Kansas City, Mo.		Nov. 27, 1917
MCMILLAN, W. BRUCE. 1st Lieut., Engrs., U. S. R., Am. Exp. Forces, France	Jun. Assoc. M.	Jan. 7, 1913 Jan. 14, 1918
MCPHERSON, ALBERT MORTIMER. Gen. Supt., Delta Land & Water Co., Milford, Utah		Jan. 14, 1918

ASSOCIATE MEMBERS (*Continued*)		Date of Membership.
Mathias, Jared Leroy. Junior Highway Engr., U. S. Office of Public Roads, Mills Bldg., San Francisco, Cal.	Jun. Assoc. M.	Oct. 1, 1913 Jan. 14, 1918
Mitchell, William Montgomery. Asst. Supt., Flint City Water-Works, 618 Church St., Flint, Mich.		Jan. 14, 1918
Needham, Egbert Stephen. 109 North 5th St., Livingston, Mont.		Nov. 27, 1917
Openshaw, John Edward. Cost Engr., Dominion Bridge Co., Ltd., Montreal, Que., Canada		Jan. 14, 1918
Pasco, Benjamin Gilbert. Woods Supt., A. J. Neimeyer Lumber Co., Little Rock, Ark.		Jan. 14, 1918
Petry, Charles Aloysius. Designer and Supt. of Constr., Superv. Archt.'s Office, Univ. of Illinois, 256 Administration Bldg., Urbana, Ill.		Nov. 27, 1917
Peyton, Ashton Ramsay. Contr. Engr., Virginia Bridge & Iron Co., 503 First National Bank Bldg., Denver, Colo.		Jan. 14, 1918
Russell, Earle. Contr. Engr. (Ellison & Russell), 251 Kearny St., San Francisco, Cal.		Jan. 14, 1918
Schlick, William Japhia. Drainage Engr., Eng. Experiment Station, Iowa State Coll., 717 Seventh St., Ames, Iowa		Jan. 14, 1918
Stevenson, Markley. Sales Agt., The General Crushed Stone Co., 204 Cutler Bldg., Rochester, N. Y.		Sept. 11, 1917
Stockbridge, David Field. Engr. in Chg., Designs and Plans, Capitol Steel & Iron Co., R. F. D. No. 1, Oklahoma, Okla.		Jan. 14, 1918
Sweetser, Ernest Osgood. Capt., Engrs., U. S. R. (*Unattached*), Am. Exp. Forces, France		Nov. 27, 1917
Sykes, Gaither Hunter. Howard House, Elkton, Md.		Jan. 14, 1918
Sykes, James. Engr., G. W. Ry., P. O. Box 395, Loveland, Colo.		Jan. 14, 1918
Volk, Wendell Douglas. 1st Lieut., Engrs. U. S. R., Co. E, 20th Engrs., Am. Exp. Forces, France		Sept. 11, 1917
Voss, Walter Charles. Head, Dept. of Architectural Constr., Wentworth Inst., 22 Garrison Rd., Brookline, Mass.		Jan. 14, 1918
Wade, Jeptha A. Field Engr., British Chemical Co., Hotel York, New York City		Nov. 27, 1917
Wheeler, Henry Lewis. Superv. of Roadway and Structures, San Joaquin & Eastern R. R., Auberry, Cal.		Jan. 14, 1918
White, Frank Osmond. 200 Fifth Ave., New York City		Jan. 14, 1918

JUNIORS

Cleckner, Frederick Martin. 1530 Green St., Harrisburg, Pa.	Jan. 14, 1918

JUNIORS (*Continued*)

	Date of Membership.
Darling. Clinton Stowell. 2d Lieut., Co. A. 108th Engrs., Camp Logan, Houston, Tex.; Box 144, South Vernon, Mass.	Jan. 14, 1918
Elliott, Percival. Care, Valuation Dept., N. & W. Ry., Roanoke, Va	Jan. 14, 1918
Fickes, Eugene Weldon. 533 East Orange St., Lancaster, Pa.	Sept. 11, 1917
Fogerty, Merton Shumway. Engr. and Draftsman, Odell Mfg. Co., Box 493, Groveton, N. H	Oct. 9, 1917
Humann, Edwin August. Co. D, 4th Engrs. U. S. A., Camp Greene, Charlotte, N. C.; 811 First National Bank Bldg., Oakland, Cal	Nov. 27, 1917
Jewell, Albert Hartwell. 1st Lieut., Sig. Corps, Aviation School, Post Hospital, Mount Clemens, Mich.; Address, 313 Clinton St., Adrian, Mich	Jan. 14, 1918
Larkin, Charles Raymond. Asst. Engr., Bureau of Health, 2242 West Lehigh Ave., Philadelphia, Pa	Jan. 14, 1918
Levy, Joseph Irwin. 679 Ave. C, Bayonne, N. J	Nov. 27, 1917
Preston, John Owings. 501 Arlington Bldg., Rochester, N. Y	Jan. 14, 1918

REINSTATEMENTS

ASSOCIATE MEMBERS

	Date of Reinstatement.
Gehring, Herbert August	Jan. 14, 1918

RESIGNATIONS

MEMBERS

	Date of Resignation.
Burger, William Henry	Dec. 31. 1917
Fendall, Benjamin Truman	Dec. 31, 1917
Stone, Everett Edward	Dec. 31, 1917

ASSOCIATE MEMBERS

Brown, Samuel Coughlin	Dec. 31, 1917
Coltman, Robert, Jr	Dec. 31, 1917
Davis, Fred Rufus	Dec. 31, 1917
Decker, Frank Warwick	Dec. 31, 1917
Fraser, De Gennes	Dec. 31, 1917
Fuqua, Paul David	Dec. 31, 1917
Moore, Walter Smyth	Dec. 31, 1917
Riggs, Charles Albert	Dec. 31, 1917

JUNIORS

Harrington, Wellesley Carl	Dec. 31, 1917
Henes, Harry William	Dec. 31, 1917
Parsons, Maurice Giesy	Dec. 31, 1917
Truesdell, Archie Merle	Dec. 31, 1917

DEATHS

BRADFORD, WILLIAM. Elected Member, December 7th, 1898; died November 23d, 1917.

CANNEY, JAY CASSIUS. Elected Junior, May 31st, 1916; died September 15th, 1917.

CURRAN, THOMAS FRANCIS. Elected Associate Member, August 31st, 1915; died January 8th, 1918.

HAGUE, WILLIAM. Elected Associate Member, October 4th, 1910; died January 1st, 1918.

Total Membership of the Society, February 7th, 1918, 8 612.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(October 1st to 31st, 1917)

NOTE.—*This list is published for the purpose of placing before the members of this Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(2) *Journal*, Engrs. Club of Phila., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *Journal*, Am. Inst. Architects, Washington, D. C., 50c.
(7) *Gesundheits Ingenieur*, München, Germany.
(8) *Stevens Indicator*, Hoboken, N. J., 50c.
(9) *Industrial Management*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, 432 Fourth Ave., New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News-Record*, New York City, 15c.
(15) *Railway Age*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Electric Railway Journal*, New York City, 10c.
(18) *Railway Review*, Chicago, Ill., 15c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 20c.
(21) *Railway Engineer*, London, England, 1s. 2d.
(22) *Iron and Coal Trades Review*, London, England, 6d.
(23) *Railway Gazette*, London, England, 6d.
(24) *American Gas Engineering Journal*, New York City, 10c.
(25) *Railway Mechanical Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England, 4d.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Royal Society of Arts, London, England, 6d.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium, 4 fr.
(31) *Annales* de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand, Brussels, Belgium, 4 fr.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France, 1 fr.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *Cornell Civil Engineer*, Ithaca, N. Y.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Technisches Gemeindeblatt*, Berlin, Germany, 0, 70m.
(40) *Zentralblatt der Bauverwaltung*, Berlin, Germany, 60 pfg.
(41) *Electrotechnische Zeitschrift*, Berlin, Germany.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governors Island, New York Harbor, 50c.
(45) *Coal Age*, New York City, 10c.
(46) *Scientific American*, New York City, 15c.
(47) *Mechanical Engineer*, Manchester, England, 3d.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany, 1, 60m.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia, 25 kop.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Vereines, Vienna, Austria, 70h.
(54) *Transactions*, Am. Soc. C. E., New York City, $12.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.

(56) *Transactions,* Am. Inst. Min. Engrs., New York City, $6.
(57) *Colliery Guardian,* London, England, 5d.
(58) *Proceedings,* Engrs.' Soc. W. Pa., 2511 Oliver Bldg., Pittsburgh, Pa., 50c.
(59) *Proceedings,* American Water-Works Assoc., Troy, N. Y.
(60) *Municipal Engineering,* Indianapolis, Ind., 25c.
(61) *Proceedings,* Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Drop Forger,* Thaw Bldg., Pittsburgh, Pa., 10c.
(63) *Minutes of Proceedings,* Inst. C. E., London, England.
(64) *Power,* New York City, 5c.
(65) *Official Proceedings,* New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Gas Journal,* London, England, 6d.
(67) *Cement and Engineering News,* Chicago, Ill., 25c.
(69) *Der Eisenbau,* Leipzig, Germany.
(71) *Journal,* Iron and Steel Inst., London, England.
(71*a*) *Carnegie Scholarship Memoirs,* Iron and Steel Inst., London, England.
(72) *American Machinist,* New York City, 15c.
(73) *Electrician,* London, England, 18c.
(74) *Transactions,* Inst. of Min. and Metal., London, England.
(75) *Proceedings,* Inst. of Mech. Engrs., London, England.
(76) *Brick,* Chicago, Ill., 20c.
(77) *Journal,* Inst. Elec. Engrs., London, England, 5s.
(78) *Beton und Eisen,* Vienna, Austria, 1, 50m.
(79) *Forscherarbeiten,* Vienna, Austria.
(80) *Tonindustrie Zeitung,* Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen,* Wiesbaden, Germany.
(83) *Gas Age,* New York City, 15c.
(84) *Le Ciment,* Paris, France.
(85) *Proceedings,* Am. Ry. Eng. Assoc., Chicago, Ill.
(86) *Engineering and Contracting,* Chicago, Ill., 10c.
(87) *Railway Engineering and Maintenance of Way,* Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.
(89) *Proceedings,* Am. Soc. for Testing Materials, Philadelphia, Pa., $5.
(90) *Transactions,* Inst. of Naval Archts., London, England.
(91) *Transactions,* Soc. Naval Archts. and Marine Engrs., New York City.
(92) *Bulletin,* Soc. d'Encouragement pour l'Industrie Nationale, Paris, France.
(93) *Revue de Métallurgie,* Paris, France, 4 fr. 50.
(95) *International Marine Engineering,* New York City, 20c.
(96) *Canadian Engineer,* Toronto, Ont., Canada, 10c.
(98) *Journal,* Engrs. Soc. Pa., Harrisburg, Pa., 30c.
(99) *Proceedings,* Am. Soc. of Municipal Improvements, New York City, $2.
(100) *Professional Memoirs,* Corps of Engrs., U. S. A., Washington, D. C., 50c.
(101) *Metal Worker,* New York City, 10c.
(102) *Organ für die Fortschritte des Eisenbahnwesens,* Wiesbaden, Germany.
(103) *Mining and Scientific Press,* San Francisco, Cal., 10c.
(104) *The Surveyor and Municipal and County Engineer,* London, England, 6d.
(105) *Metallurgical and Chemical Engineering,* New York City, 25c.
(106) *Transactions,* Inst. of Min. Engrs., London, England, 6s.
(107) *Schweizerische Bauzeitung,* Zürich, Switzerland.
(108) *Southern Machinery,* Atlanta, Ga., 10c.
(109) *Journal,* Boston Soc. C. E., Boston, Mass., 50c.
(110) *Journal,* Am. Concrete Inst., Philadelphia, Pa., 50c.
(111) *Journal of Electricity, Power and Gas,* San Francisco, Cal., 25c.
(112) *Internationale Zeitschrift für Wasser-Versorgung,* Leipzig, Germany.
(113) *Proceedings,* Am. Wood Preservers' Assoc., Baltimore, Md.
(114) *Journal,* Institution of Municipal and County Engineers, London, England, 1s. 6d.
(115) *Journal,* Engrs.' Club of St. Louis, St. Louis, Mo., 35c.
(116) *Blast Furnace and Steel Plant,* Pittsburgh, Pa., 15c.

LIST OF ARTICLES

Bridges.

The 186 Ft. Bascule Bridge of the C. & N. W. Ry., Over the North Branch of the Chicago River at Deering.* O. F. Dalstrom. (4) Sept.
Another Large Railroad Bridge Completed.* (15) Sept. 14.
Economics of Bridge Design. J. A. L. Waddell. (Abstract of lecture before School of Eng., Univ. of Kansas.) (96) Oct. 11.
The James River Bridge.* (19) Oct. 13.
Bridge Spans Moved Endwise to Rest on New Piers.* (13) Oct. 25.
Ponts Flottants sur le Mississippi pour le Passage du Milwaukee and St. Paul Railway.* P. Calfas. (33) Oct. 27.
L'Achèvement du Pont de Québec.* (33) Nov. 17.

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* Illustrated.

Electrical.

Improved Elevating Industrial Truck. (20) Sept. 6.
Means to Economy from Motor Driven Mills.* D. M. Petty. (Abstract of paper read before the Assoc. of Iron and Steel Elec. Engrs.) (20) Sept. 13.
Economic Industrial Applications of Electricity. Norman T. Wilcox. (4) Oct.
Cross-Current Predeterminations from Crank-Effort Diagrams.* Louis Illmer Milford. (55) Oct.
Central Station Power for Steel Mills.* Joseph McKinley and Roy L. Bauer. (116) Oct.
Modern Hardware Store Lighting.* C. E. Clewell. (108) Oct.
Electric Code: Adopted by the Industrial Board, Pennsylvania Department of Labor and Industry, Operative on and After July 1, 1917. (2) Oct.
Appleton Water-Steam Plant.* Thomas Wilson. (64) Oct. 2.
The Significance of Load Graphs.* Terrell Croft. (64) Oct. 2.
Underground Telephone Cables. George Viard. (Abstract of article in *Annales des Postes, Télégraphes et Teléphones.*) (73) Oct. 5.
Electric Haulage at Delagua Collieries. F. Hoskinson. (57) Oct. 5.
The Commutation of Large Continuous-Current Generators and Rotary Converters Under Heavy Overload Conditions.* H. G. Bell. (Abstract of paper in *Journal* of the Municipal School of Technology.) (73) Oct. 5.
An Approximate Method of Checking the Accuracy of a Direct-Reading Insulation Testing Set.* G. W. Stubbings. (26) Oct. 5.
Improved Method of Testing Current Transformers.* Francis B. Silsbee. (27) Oct. 6.
Mechanical Analogies in Electricity.* Wilson C. Morris. (19) Oct. 6.
Making System Adequate for Increased Loads. P. O. Reyneau. (27) Oct. 6.
Street Lighting for Business Districts.* James R. Cravath. (27) Oct. 6.
Reducing the Peak Load by a Remotely Controlled Water-Works Pumping Unit.* (86) Oct. 10.
The Princep's "Deflector" Air Filter.* (22) Oct. 12.
Ultra-Violet Radiation. Charles A. Schunck. (Abstract of a paper read before the Röntgen Soc.) (19) Oct. 13.
Charging Racks for Miners' Lamp Batteries. (45) Oct. 13.
Some Difficulties with Iron-Wire Transmission.* M. D. Leslie. (27) Oct. 13.
Shimming Field Poles Cures Troubles with Alternator.* E. Hagenlocher. (27) Oct. 13.
Iron-Wire Transmission for Rural Extensions.* L. P. Perry. (27) Oct. 13.
The Electrical Dealer's Profits. A. H. Halloran. (111) Oct. 15.
Radio-Activity and Some Advances in Physical Science. Howard H. Barker. (Paper read before the Teknik Club.) (105) Oct. 15.
Power Plant Calumet Terminal Elevator.* Thomas Wilson. (64) Oct. 16.
Frequency-Changer Sets.* Quentin Graham. (64) Serial beginning Oct. 16.
Open and Enclosed Type Fuses.* A. B. Eason. (73) Oct. 19.
Setting Wood Poles for Seventy Cents Each.* Allan C. Haskell. (17) Oct. 20.
D.-C.-Excited Transformers as Current-Limiting Reactors.* (27) Oct. 20.
Design of Solenoids and Plunger Magnets.* George L. Hedges. (27) Oct. 20.
Rating Artificial Lighting Systems. Davis H. Tuck. (27) Oct. 20.
Disturbance of Telegraphic Communication in the Rhone Valley Through the Operation of the Lötschberg Electric Railway.* M. Dumermuth. (Abstract of an article in *Elektrotechnische Zeitschrift.*) (73) Oct. 26.
The Squirrel Cage Speed Indicator.* E. B. Brown. (73) Oct. 26.
A Technical Specification for Metal Filament Glow Lamps. (Abstract of an article in *Bulletin* of the Association Suisse des Electriciens.) (73) Oct. 26
Internal Relations in Audion-Type Radio Receivers.* Ralph Bown. (Abstract of article in *Physical Review.*) (73) Oct. 26.
Magneto Flash Lamp.* (26) Oct. 26.
Inductive and Electrostatic Troubles Arising from A. C. Railways. (26) Oct. 26.
The Development of the Coherer.* E. C. Green. (From the *General Electric Review.*) (19) Oct. 27.

Marine.

Aviation as Applied to the Navy. George D. Murray. (109) Oct.
Mare Island Navy Yard.* (72) Oct. 11.
United States Standard Twin-Screw Wooden Steamships.* (11) Oct. 12.
Four-Slip Shipyard Compactly Arranged on City Property. (13) Oct. 18.
Les Chalands et Navires en Béton Armé; Construction des Navires *Beton I* et *Namenfjords* à Porsgrund et à Moss (Norvège).* (33) Dec. 1.
Les Nouveaux Navires de Commerce en Acier des États-Unis.* (33) Dec 8.
La Défense du Commerce Maritime Contre les Sous-Marins.* (33) Serial beginning Dec. 15.

Mechanical.

Use of Producer Gas Without Regenerators.* John H. Bartlett, Jr. (20) Aug. 2.
Devices to Facilitate Shell-Machining.* Enos Moore. (20) Aug. 2.
A 12-In. Lathe for Toolroom Work. (20) Aug. 2.

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* Illustrated.

Mechanical—(Continued).

The Use and Abuse of Steel for Aircraft.* R. K. Bagnall-Wild and E. W. Birch. (Abstract of paper read before the Institution of Automobile Engrs.) (20) Aug. 9.
Electric Steel for Roller Bearings.* (20) Aug. 9.
New Plant of Pyle-National Company.* (20) Aug. 16.
Lathe for Turning Torpedo Heads.* (20) Aug. 23.
Expansion of the Gier Pressed Steel Co.* Charles Lundberg. (20) Aug 23.
Gas Fired Welding Furnace.* Charles E. Richardson. (20) Aug. 23.
Recovery of Coke Breeze at Skip Hoists.* (20) Aug. 30.
The Preparation of Rock Products.* Raymond W. Dull. (4) Sept.
Planning Department in Modern Shops. (Abstract of paper read before Providence Eng. Soc.) (20) Sept. 6.
Compressed Coal Gas for Motor Lorries. (104) Sept. 7.
Graphite Lubrication. (20) Sept. 13.
New Air-Carried Powdered Coal Plant.* (20) Sept. 27.
Huge Floating Crane.* (20) Sept. 27.
The Trumble Refining Process (for Oil).* N. W. Thompson. (55) Oct.
The Transfer of Heat Between a Flowing Gas and a Containing Flue.* Lawford H. Fry. (55) Oct.
Plate Mills for Rolling Sheared Plates. F. C. Biggert. (116) Oct.
By-Product Coke Oven Pressure Regulation.* W. Trinks. (116) Oct.
Improving Blast Furnace Blowing Engines.* (116) Oct.
Characteristics of Roller Bearings.* P. B. Liebermann. (116) Oct.
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Eliminating Unproductive Time.* Holden A. Evans. (9) Oct.
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Forging Machine Work at Silvis Shops.* (35) Oct.
Aviation as Applied to the Navy. George D. Murray. (109) Oct.
How to Compute Strength of Boiler Shells in Fuel Oil Practice.* Robert Sibley and Chas. H. Delany. (111) Oct. 1.
Encouraging Modern Methods in Gas Lighting.* (83) Oct. 1.
Gas Mantle Lighting Conditions in the United States. R. S. McBride and C. E. Reinicker. (Abstract of *Technical Paper No. 99.*) (83) Oct. 1.
Present Status and Prospects of Gas Lighting. Wm. J. Serrill. (83) Oct. 1.
Calculating Leakage of Gas in Mains.* (83) Oct. 1.
Test of a Rotary Pump.* (83) Oct. 1.
The Production and Prevention of Naphthalene. Thomas D. Miller. (From the *American Gas Inst. News.*) (66) Serial beginning Oct. 2.
High Speed of Steam Turbines. W. F. Schaphorst. (64) Oct. 2.
Building a Military Training Airplane.* Fred H. Colvin. (72) Oct. 4.
Safety Engineering at the Winchester Repeating Arms Company.* C. B. Hayward. (72) Oct. 4.
Timken Plant for Heat-Treating Axles. (20) Oct. 4.
The Petrol Tractor on the Farm.* (Abstract of a paper read before the Soc. of Agricultural Engrs.) (12) Oct. 5.
Notes on the Present Knowledge and Practice in Regard to the Briquetting of Iron Ores. Guy Barrett and T. B. Rogerson. (12) Oct. 5.
Construction and Working of Boilers in Intensive Service. (22) Oct. 5.
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Ideal Shop for Sharpening Drill Steel.* George H. Gilman. (16) Oct. 6.
Saving of 79.7 Per Cent. in Floor Space But One of Many Advantages Gained by Replacing Oil-Burning Tile-Drying Installation by Gas.* F. H. Mugg. (24) Oct. 6.
Converting Existing Smoke-Houses to Gas.* Gilbert C. Shadwell. (24) Oct. 6.
Test Removes Uncertainty as to Quantity of Air Rotary Pump Will Handle.* (24) Oct. 6.
Can the Yield of Benzol Derivatives Be Improved by Carbonizing Coal at Lower Temperatures? Norton H. Humphrys. (24) Oct. 6.
Drop in Pressure of Compressed-Air Hose.* Walter S. Weeks. (103) Oct. 6.
Modern Clay Testing. Arthur E. Williams. (76) Serial beginning Oct. 9.
Using Hot Gases from Burning Kilns to Dry Clay Ware. (76) Oct. 9.
New Boilers for Ashley Street Station.* John Hunter. (64) Oct. 9.
Operation of Mechanical Stokers.* H. F. Laurence. (64) Oct.9.
Some Experiences with Intermittent Verticals.* Harold H. Collett. (Read before the North of England Gas Managers Assoc.) (66) Oct. 9.
Precision Drilling Machine.* C. E. Davies. (72) Oct. 11.
Possibilities of Rapid Growth in Airplane Work. Fred H. Colvin. (72) Oct. 11.
On the Testing of Refractory Materials.* J. W. Mellor. (Read before the Ceramic Soc.) (11) Oct. 12; (16) Oct. 9; (66) Oct. 9; (22) Oct. 5.
The Use of Culm and Other Waste Fuels.* John C. B. Kershaw. (12) Oct. 12.

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The Utilization of Undeveloped Fuels in Pulverized Form.* (26) Oct. 12.
Principles and Methods of a New System of Gas-Firing.* A. C. Ionides. (12) Oct. 12.
Suction Gas from South African Coals. F. C. Sturrock and E. T. Way.* (From *Journal* of the South African Institution of Engrs.) (57) Oct. 12.
New Coke Ovens and By-Product Plant at Bearpark Brancepeth Colliery, Durham.* (22) Oct. 12.
Refractories and Modern Kilns. J. G. Maxwell. (Paper read before the Ceramic Soc.) (11) Oct. 12.
On the Refractory Properties of Silica. H. Le Chatelier and B. Bogitch. (Abstract of paper read before the Ceramic Soc.) (11) Oct. 12.
Recovering Sulphur from Coal. (57) Oct. 12.
Time Near at Hand When Practically All of the Country's Coffee Will Be Gas Roasted.* H. E. Danner. (24) Oct. 13.
The Synthetic Making of Sodium Cyanide.* G. H. Clevenger. (103) Oct. 13.
Efficiency and Utilization of Gas in Top Burners.* Charles Norman Cross. (Paper read before Pacific Coast Gas Assoc.) (83) Oct. 15.
Storage, Weathering and Spontaneous Combustion of Coal. (105) Oct. 15.
Fractional Combustion. Wilder D. Bancroft. (Paper read before the Am. Electrochemical Soc.) (105) Oct. 15.
Furnaces in Fuel Oil Practice.* Robert Sibley and Chas. H. Delany. (111) Oct. 15.
Gas-Driven Motor Vehicles. (66) Oct. 16.
Simmance's Total-Heat Recording Calorimeter.* (66) Oct. 16.
How Dull Tools Displace the Grain of Bearing Metals.* Christopher H. Bierbaum. (72) Oct. 18.
Oxyacetylene Repairs.* Charles Shaeff. (72) Oct. 18.
Plant for Large Output of 1918 Castings.* (20) Oct. 18.
Sub-Committee on Coal-Tar By-Products Issues Condensed Report on Recovery of Toluol from Gas Works.* (24) Oct. 20.
Some Troubles of Steam Turbines. Eugene Bak. (64) Oct. 23.
Notes on the Flow of Clay Through Hollow Ware Dies.* George D. Morris. (Reprinted from *Transactions* of the Am. Ceramic Soc.) (76) Oct. 23.
Using Instruments in Dryer Regulation.* (76) Oct. 23.
A Study of Velocity Diagrams for Shapers and Slotters.* A. Lewis Jenkins. (72) Serial beginning Oct. 25.
An Outfit for Making Painted Roll Tin.* (101) Oct. 26.
Working Costs of Prime Movers.* Oswald Wans. (57) Oct. 26; (26) Oct. 26.
Importance of Flexibility of Boiler Control. Victor B. Phillips. (27) Oct. 20.
Pulverized Fuel in Brazil.* (18) Oct. 27.
The Measurement of High Temperatures. Henry Le Chatelier. (19) Oct. 27.
Gas Displaces Oil as Industrial Fuel in Western Tractor Factory.* Harry L. Wolff. (24) Oct. 27.
Effect on Consuming Devices of Mixed Artificial and Natural Gas. Frank S. Honberger. (24) Oct. 27.
The Gas Appliance Testing Laboratory.* H. M. Riley and L. B. Wilson, Jr. (24) Serial beginning Oct. 27.
Recent Progress in Internal-Combustion Engine Valve Gears.* R. E. Mathot. (64) Oct. 30.
Les Tracteurs aux Essais de Noisy-le-Grand.* (92) Sept.
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Trois Ans d'Expériences sur l'Aéroplane. J. Legrand. (92) Sept.
L'Utilisation Rationnelle du Charbon en Allemagne, et la Gazéification Complète des Combustibles Solides. René Schmutz. (33) Nov. 3.
La Consommation et la Production du Sel. Nicolas Flamel. (33) Serial beginning Nov. 17.
Die Stützung von Dampfkesseln und von Wasserleitungen.* E. Höhn. (107) Nov. 3.
Die Verwendung von Holz und Torf in den Gaswerken. E. Ott. (107) Nov. 24.

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Grinding as a Substitute for Milling.* (20) Aug. 2.
Manganese in Steel Making. Henry M. Howe. (Abstract of paper presented before Am. Soc. for Testing Materials.) (20) Aug. 2.
The Rôle of Chrome Vanadium in Steel. F. J. Griffiths. (Abstract of paper read before Am. Soc. for Testing Materials.) (20) Aug. 2.
Castings that Withstand High Temperatures.* (20) Aug. 2.
Refractories in the Steel Industry. Cosmo Johns. (Abstract of paper read before the Iron and Steel Inst.) (20) Aug. 2.
Rôle of Silicon in Steel Making. W. E. Ruder. (Abstract of paper read before Am. Soc. for Testing Materials.) (20) Aug. 9.
Modern Economies in Pickling Steel. J. H. Snyder. (20) Aug. 9.

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A New Thermostatic Metal.* (20) Aug. 9.
High Grade Pig Iron from Scrap Steel.* Edwin F. Cone. (20) Aug. 30.
Results of Rolling from Green Ingots.* George W. Dress. (20) Sept. 6.
The Rôle of Nickel in Making Steel. R. R. Abbott. (Abstract of paper read before Am. Soc. for Testing Materials.) (20) Sept. 13.
Structure of Iron Cast in Metal Molds.* Edwin F. Cone. (20) Sept. 20.
Electric Oven Used for Baking Cores.* (20) Sept. 20.
The Metallurgy of Titanium. Robert J. Anderson. (3) Oct.
Magnetic Analysis of Rails and Other Steel Products. Charles W. Burrows. (Abstract of a paper read before Am. Soc. for Testing Materials.) (21) Oct.
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On the Superheating of Slags and Metals During Refining, Smelting and Alloying Operations.* J. E. Fletcher. (Paper read before the Soc. of Chemical Industry.) (105) Oct. 1.
Hardening Carbon and Special Steels. L. Grenet. (Abstract of paper read before Iron and Steel Inst.) (20) Oct. 4.
The Acid Open-Hearth Process.* F. Rogers. (Paper read before the Iron and Steel Inst.) (11) Oct. 5.
Foundry Costs. F. T. Clapham. (12) Oct. 5.
The Effect of Great Hydrostatic Pressure on the Physical Properties of Metals. Zay Jeffries. (Paper read before the Inst. of Metals.) (11) Oct. 5.
Investigation Upon a Cast of Acid Open-Hearth Steel.* T. D. Morgans and F. Rogers. (Paper read before the Iron and Steel Inst.) (11) Oct. 5; (20) Oct. 18.
Present Milling Practice of the Joplin District.* Temple Chapman. (16) Oct. 6.
Heat Treatment of Metals. W. A. Ehlers. (19) Oct. 6.
Economical Generation and Use of Electric Power in the Steel Industry. Brent Wiley. (Abstract of paper read before the Assoc. of Iron and Steel Elec. Engrs. (64) Oct. 9.
Economical Production of Small Cores.* R. E. Kennedy. (Abstract of paper read before the Am. Foundrymen's Assoc.) (20) Oct. 11.
Fuel Economy Possibilities in Brass Melting Furnaces.* L. C. Harvey. (Read before the Inst. of Metals.) (11) Oct. 12; (66) Oct. 2.
Chemicals Used in Flotation. O. C. Ralston and L. D. Yundt. (103) Oct. 13.
Hazards of Low Voltage Mill Machinery. C. A. Lauffer. (Abstract of paper read before National Safety Council.) (105) Oct. 15.
Hazards of Low Voltage Mill Machinery. C. A. Lauffer. (Abstract of paper read before National Safety Council.) (105) Oct. 15.
The Treatment of Metallurgical Smoke in Japan. Tetsurow Komakine. (105) Oct. 15.
Physico-Chemical Properties of Chrome-Nickel Steels.* Herbert J. French. (105) Oct. 15.
Steel Castings for Ordnance Construction. C. M. Wesson. (Abstract of paper read before Foundrymen's Convention.) (72) Oct. 18.
Effect of Pickling on the Strength of Steel. John Coulson. (Abstract of paper read before Am. Electro-Chemical Soc.) (20) Oct. 18.
Flotation of Lead and Zinc in the Joplin District. C. A. Wright. (103) Oct. 20.
The Electric Furnace for Non-Ferrous Metallurgy.* (27) Oct. 27.
Recovery of Converter-Fumes at Tooele, Utah.* L. S. Austin. (103) Oct. 27.
Preferential Flotation. W. Shallshear. (103) Oct. 27.
L'Industrie et les Grandes Applications de l'Aluminium Pur et à l'Etat d'Alliages.* Jean Escard. (33) Serial beginning Dec. 1.

Military.

Devices to Facilitate Shell-Machining.* Enos Moore. (20) Aug. 2.
Compressed Coal Gas for Motor Lorries. (104) Sept. 7.
Industrial Specialization for a Fighting Army. G. P. Capart. (9) Oct.
Investigation of Defective Small-Arms Ammunition at Washington. (105) Oct. 1.
Construction Was Speedy at Camp Lewis: Largest of the National Army Cantonments at American Lake, Washington, Accommodating 48 000 Men, Finished in 56 Days.* Nathan A. Bowers. (13) Oct. 4.
Building a Military Training Airplane.* Fred H. Colvin. (72) Oct. 4.
Safety Engineering at the Winchester Repeating Arms Company.* C. B. Hayward. (72) Oct. 4.
Equipment of Our New Soldier Factories.* (101) Oct. 5.
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Steel Castings for Ordnance Construction. C. M. Wesson. (Abstract of paper read before Foundrymen's Convention.) (72) Oct. 18.

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Cast-Iron Shells in Permanent Molds.* Edgar A. Custer. (Paper read before Am. Foundry Assoc.) (72) Oct. 25.
Equipment of a Southern Army Cantonment.* O. Val Serviss. (101) Oct. 26.
Ventilating and Heating Soldiers' Barracks.* (101) Oct. 26.
The New War Truck.* C. H. Hardy. (46) Oct. 27.
Les Modèles Actuels de Torpilles Automobiles.* Stroh. (33) Dec. 8.

Mining.

The Shortage of the Supply of Non-Phosphoric Iron Ore.* William George Fearnsides. (29) Sept. 28.
Plant of the Columbia Quarry Company.* (67) Oct.
Electric Haulage at Delagua Collieries.* F. Hoskinson. (57) Oct. 5.
Underground Mine Sanitation. A. J. Lanza. (Abstract of paper read before the National Safety Council.) (16) Oct. 6.
Uses of Concrete in Coal Mines.* (45) Oct. 6.
Electric Winding.* D. Burns. (Paper read before the West of Scotland Branch joint meeting of the National Assoc. of Colliery Managers and Mining Inst. of Scotland.) (73) Oct. 12.
Ferro-Concrete Pit Props.* W. Marriott. (Paper read before Midland Counties Institution of Engrs.) (57) Oct. 12; (22) Oct. 12.
Equipment and Organization of Mine Rescue Stations.* A. J. Moorshead. (Paper read before National Safety Congress.) (45) Oct. 13.
Accident Statistics and the Operator. Albert H. Fay. (Abstract of paper read before the Min. Section of the National Safety Council.) (45) Oct. 13.
Charging Racks for Miners' Lamp Batteries.* (45) Oct. 13.
Alaska Juneau 1520-Ft. Raise.* C. K. White. (16) Oct. 13.
The Granby Mine at Anyox, B. C.* Wakely A. Williams. (16) Serial beginning Oct. 13.
Safety and Sociological Conditions in Utah.* R. M. Magraw. (45) Oct. 13.
Equipment Repairs in a Gold and Silver Mine.* (72) Oct. 18.
The Government Mine Rescue Cars.* D. J. Parker. (Paper read before the National Safety Council.) (45) Oct. 20.
Making Coal Cars in Mines Safe.* Carl Scholz. (Paper read before National Safety Council.) (45) Oct. 20.
Mechanical Ventilation for Metal Mines. George Rice. (103) Oct. 20.
Safe Compressive Stresses on Colliery Brickwork. W. C. Popplewell. (57) Oct. 26.
Pillar Extraction in Thick Seams.* R. W. Magraw. (45) Oct. 27.
Skip-Changing Devices at the Butte Mines.* Theodore Pilger. (103) Oct. 27.
Power Plant of the St. Joseph Lead Co.* E. L. Broome. (64) Oct. 30.
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Managing Alien Workers in War Time. Winthrop Talbot. (20) Aug. 2.
The Illiterate Worker in War Time. Winthrop Talbot. (20) Aug. 16.
The Alien and the Industrial Worker.* Winthrop Talbot. (20) Aug. 23.
Cost of Health Supervision of Employees. (20) Aug. 30.
Storage of Tar. G. F. Dunn. (Abstract of paper read before South-West of England Assoc. of Gas Managers.) (104) Sept. 14.
Practical Welfare Work in Foundries.* S. W. Ashe. (Abstract of paper read before National Safety Council.) (20) Sept. 20.
A Study of Surface Resistance With Glass as the Transmission Medium.* H. R. Hammond and C. W. Holmberg. (55) Oct.
American Research Methods. Charles H. McDowell. (4) Oct.
Relation of the Appraisal to Industrial Management. Charles W. McKay. (9) Oct.
Athletics for the Working Force.* C. B. Lord. (9) Oct.
Recreation of the Working Force.* Mary Barnett Gilson. (9) Oct.
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Practical Aspects of the Safety Movement. Arthur H. Young. (9) Oct.
Obsolescence as an Element Affecting Rates. C. E. Grunsky. (111) Oct. 1.
Packing and Plant Handling of Hazardous Chemicals. N. A. Lowry. (Paper read before the National Safety Council.) (105) Oct. 1.
Getting Potash Kelp With a Submarine Lawn Mower is a War Industry.* (72) Oct. 4.
The Fixation of Atmospheric Nitrogen. (26) Serial beginning Oct. 12.
A Further Three Years' Flying Experience. B. C. Hucks. (Abstract of a paper read before the Aeronautical Soc.) (29) Oct. 19.
Further Notes on a High-Temperature Thermostat.* J. L. Houghton and D. Hanson. (Abstract of paper read before the Inst. of Metals.) (73) Oct. 19.
Specially Ruled Sheets Have Wide Use in Drafting Room. Richard T. Dana. (13) Oct. 25.
Le Congrès des Ingénieurs à l'Exposition de San-Francisco et l'Achèvement du Canal de Panama. L. de Pulligny. (32) May.

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Tables de Division.* H. Chevalier. (32) May.
La Formation des Ingénieurs au Japon. H. Chevalier. (32) May.
Les Sourds et les Muets de la Guerre.* Lucien Fournier. (33) Nov. 3.
Formule de Prime à la Production pour le Paiement des Salaires. Louis de Contenson. (33) Dec. 1.
La Préparation de l'Acide Acétique. A. Mailhe. (33) Dec. 22.
Von der Cykloide.* A. Kiefer. (107) Dec. 8.

Municipal.

Is State Subsidy for Housing Desirable? If So, on What Principle? Bailie A. W. Paton. (Abstract of paper read before the Incorporated Sanitary Assoc. of Scotland.) (104) Sept. 14.
Housing the Worker and His Family. Peter Fyfe. (Abstract of paper read before the Incorporated Sanitary Assoc. of Scotland.) (104) Sept. 14.
Tenements as Against Cottages in City Areas. James Thomson. (Abstract of paper read before Incorporated Sanitary Assoc. of Scotland.) (144) Sept. 14.
Government Housing Scheme, Well Hall, Kent.* (104) Sept. 28.
Remodelling of Civic Asphalt Plant, Ottawa.* L. McLaren Hunter. (96) Oct. 25.
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Survey Methods Used on the Wilson Avenue Tunnel, Chicago, Ill.* H. W. Clausen. (4) Sept.
Wooding's Automatic Train-Stop.* (15) Sept. 14.
Large Capacity Tank Cars for the Santa Fé. (15) Sept. 14; (25) Oct.
Progress in Accident Prevention. Marcus A. Dow. (Abstract of address before National Safety Council.) (15) Sept. 14.
Salvaging Rolling Stock on the Santa Fé. (15) Sept. 14.
Federal Inspection Requirements.* (Abstract of a report published by General Foremen's Assoc.) (25) Oct.
Boiler Shop Apprenticeship Methods. (25) Oct.
Unique Underframe Reinforcement.* (25) Oct.
Freight Car Maintenance.* Lewis K. Sillcox. (25) Oct.
Magnetic Analysis of Rails and Other Steel Products. Charles W. Burrows. (Abstract of a paper read before Am. Soc. for Testing Materials.) (21) Oct.
Forging Machine Work at Silvis Shops.* (25) Oct.
Freight Car Maintenance.* Lewis K. Sillcox. (25) Oct.
The Economies of Car Design. John A. Pilcher. (25) Oct.
Steel Car Shop of the E. J. & E.* (25) Oct.
Cross Balance of Locomotives.* C. H. Faris. (25) Oct.
Height of Firedoors.* (25) Oct.
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Preliminary Locomotive Design.* W. R. Maurer. (25) Oct.
Russian Decapod Locomotives.* (25) Oct.; (13) Oct. 12.
Standardization and Improved Locomotive Service. George Armstrong. (25) Oct.
Safety Bar Between Engine and Tender.* (21) Oct.
The Conservation of Material.* M. K. Barnum. (Paper read before N. Y. R. R. Club.) (65) Oct.
Wheel Work and Other R. R. Shop Operations.* Frank A. Stanley. (72) Oct. 4.
Steel Tower Carries Clock and Water Tank.* (13) Oct. 4.
The Government Position on Valuation. C. A. Prouty. (15) Oct. 5.
New Locomotive on the South-Eastern and Chatham Railway.* (12) Oct. 5.
New P. R. R. Locomotive Has Powerful Electrical Equipment. (17) Oct. 6.
Steel Supply Cars,, Norfolk & Western Railway.* (18) Oct. 6.
The Effect of the Brick Arch on Locomotive Smoke Abatement. J. T. Anthony. (Abstract of paper read before Smoke Prevention Assoc.) (18) Oct. 6.
Making an Electric Locomotive Engineer Out of a Steam Locomotive Engineer. W. F. Coors. (18) Oct. 6.
Some Present-Day Problems in Railway Maintenance Work. F. B. Tapley. (Abstract of paper read before the Canadian Ry. Club.) (96) Oct. 11.
Making the Valuation Records Permanent. James G. Wishart. (13) Oct. 11.
Boiler Work in a Nevada Railroad Shop.* Frank A. Stanley. (72) Oct. 11.
The Virginian Railway.* (12) Oct. 12.
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Electrically-Operated Locomotive Turntable.* (11) Oct. 12.
Power Plant Supervision on the Baltimore & Ohio.* (15) Oct. 12.
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Split Head and Internal Stresses in Rails.* (18) Oct. 13.
Cause and Prevention of Astray Freight. J. J. Quirk. (18) Oct. 13.
The Self-Contained Railway Motor Car.* Raymond S. Zeitler. (18) Oct. 13.
Locomotive Frame Work.* Frank A. Stanley. (72) Oct. 18.
Three Electricians for Twenty-eight 2400-Volt D. C. Locomotives.* 17) Oct. 20.
Locomotive Design and Construction from the Maintenance Standpoint. W. H. Winterrowd. (Paper read before Canadian Ry. Club.) (18) Oct. 20.

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Inspection of Rails During Manufacture. C. W. Gennet, Jr. (Abstract of paper read before Roadmasters' and Maintenance of Way Assoc.) (18) Oct. 20.

Housing and Feeding Bridge and Building Crews.* F. E. Weiss. (Abstract of paper read before Am. Ry. Bridge and Building Assoc.) (18) Oct. 20.

Gasoline Motive Power on Far Western Railways.* (17) Oct. 20.

A Railroad Blacksmith Shop.* Frank A. Stanley. (72) Oct. 25.

Disturbance of Telegraphic Communication in the Rhone Valley Through the Operation of the Lötschberg Electric Railway.* M. Dumermuth. (Abstract of an article in *Elektrotechnische Zeitschrift.*) (73) Oct. 26.

Why a Railway Should Equip with Block Signals and Interlocking. Henry M. Sperry. (18) Oct. 27.

Les Chemins de Fer aux Etats-Unis, Impressions Recueillies au Cours d'une Visite.* J. Carlier. (33) Serial beginning Nov. 3.

Tour "Pond" pour la Tournage des Roues de Wagons Calées sur leurs Essieux.* (33) Nov. 24.

Nouvelles Locomotives du South Eastern and Chatham Railway (Angleterre).* (33) Dec. 29.

Les Chemins de Fer à Faible Trafic des Grands Réseaux après la Guerre; Réduction du Nombre des Employés et des Dépenses d'Exploitation. Claise. (33) Dec. 29.

Groupes Electrogènes pour l'Eclairage et le Démarrage des Voitures Automobiles.* (33) Dec. 29.

Compagnie des Chemins de fer du Midi: Le Conducteur de Retour du Courant Alternatif de Traction. (33) Dec. 29.

Geologische und hydrologische Beobachtungen über den Mont d'Or-Tunnel und dessen anschliessende Gebiete.* H. Schardt. (107) Serial beginning Dec. 8.

Präzisions-Nivellement durch den Gotthardtunnel 15./21. Juli, 1917. H. Zölly. (107) Dec. 8.

Ueber die Verwendbarkeit eiserner Fahrleitungen für Wechselstrombahnen.* W. Kummer. (107) Dec. 22.

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Union of South Africa Municipal Electrical Undertakings. E. Poole. (Abstract of paper read before the Engr. Section of the Natal Soc. for the Advancement of Science and Art.) (26) Serial beginning Oct. 5.

Laying Concrete Track Base Without Storing Materials on Streets.* Edward A. West. (17) Oct. 6.

Re-Engineering an Interurban Line.* (17) Oct. 6.

How Some Difficult Special Work Repair Jobs Were Accomplished.* W. L. Whitlock. (17) Oct. 13.

Boston Substation Built Between Subway and Surface Tracks.* (17) Oct. 27.

Denver's New Storage Yard Served by a Single 100-Ft. Derrick.* Edward A. West. (17) Oct. 27.

Do Changing Conditions Favor Constant-Speed Railway Motors?* R. E. Hellmund. (17) Oct. 27.

Roads and Pavements.

The Effect of Modern Traffic Upon Urban Roads and Tramway Tracks. E. W. Cockerlyne. (104) Sept. 28.

The Recent Revision of Ideas About Brick Pavement Construction. (60) Oct.

Present Practice in the Construction of Brick Pavements in Chicago. H. J. Fixmer. (60) Oct.

Sheet Asphalt for Country Roads.* E. A. Trego. (86) Oct. 3.

Roller Method of Finishing Concrete Roads as Used by Vermilion County, Illinois.* P. C. McArdle. (86) Oct. 3; (13) Oct. 4.

Instructions of Kentucky Department of Public Roads for Making Road Surveys and Estimates. (86) Oct. 3.

La Salle's Concrete Causeway Has Become Popular.* H. K. Higgins. (13) Oct. 4.

Clinker Asphaltic Macadam, Hounslow. J. G. Carey. (04) Oct. 5.

Grouted Granite Block Laid Under Congested Traffic Conditions.* (13) Oct. 11.

Stone-Gravel Road Proves Its Usefulness in Michigan. Donald A. Thomas. (13) Oct. 11.

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Intercepting Sewer Construction in the Northern Part of the Sanitary District of Chicago.* H. R. Abbott. (4) June.

The Collection and Disposal of Refuse and Nightsoil in Singapore. W. K. Symonds. (104) Sept. 7.

Construction Plant and Methods Employed in Building the Woodville Avenue Sewer, Toronto, Ont.* (60) Oct.

Toronto Incinerator Exceeds Burning Capacity Guarantee by 133 Per Cent. (60) Oct.

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Various Methods of Dewatering Activated Sludge. Edward Bartow. (60) Oct.

Hygienic and Sanitary Equipment. John Roach. (9) Oct.

Spokane's Steam Heating System.* (111) Oct. 1.

Richmond Constructs Immense Combined Sewer.* Charles E. Bolling. (13) Oct. 4.

Two Toronto Sewers Built on Piles and Timber Bents.* W. G. Cameron. (96) Oct. 4.

Possibilities of the Vacuum Heating System.* Harold L. Alt. (101) Serial beginning Oct. 5.

Equipment of Our New Soldier Factories.* (101) Oct. 5.

Public Abattoirs. R. L. Honey. (Abstract of paper read before Royal Sanitary Inst.) (104) Oct. 5.

Hot-Water Heating Under Forced Circulation.* Charles D. Allan. (64) Serial beginning Oct. 9.

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PAPERS AND DISCUSSIONS

FEBRUARY, 1918

Vol. XLIV. FEBRUARY, 1918. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

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DETERMINATION OF THE DUTY OF WATER BY ANALYTICAL EXPERIMENT

By W. C. Hammatt, M. Am. Soc. C. E.

To be Presented March 20th, 1918.

Synopsis.

The purpose of this paper is to show the methods used in the determinaton of the quantity of water required for the growth of certain crops, where it was impracticable to measure it directly. This was done by analyses of the requirements and by the separate determination, by experiment, of the specific quantity required for the different parts which go to make up the whole use of water by the plant. The circumstances attending the investigation described herein were such as to open up a new field which is not covered to any great extent in available technical literature. The writer hopes that the description of his work in this case will bring forth discussion from others who may have treated this matter along similar or different lines, as this may broaden the scope of the literature on this very important subject.

The term "duty of water" has no hard and fast definition, and is considered by various investigators as representing different things. Some consider it to be the average annual quantity, in acre-feet, applied

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Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

by the farmers in a particular locality or on a certain class of soil to produce their crops. Others consider it as the minimum quantity which, if applied under certain conditions, will produce a crop. The writer considers it in these pages as the quantity which can be applied with the greatest efficiency, under given conditions, for the production of crops.

Many researches have been made in various States and agricultural localities by the Office of Experiment Stations or by State agricultural colleges, professing to obtain the duty of water for the particular localities and under the particular conditions obtaining in the area covered by the investigations. Among the most complete of these are those of Don H. Bark,* and the United States Department of Agriculture.† These investigations attempted to fix the economical duty by dividing each tract into three parcels, applying different quantities of water to each, and observing the results. This was a step ahead of any work done heretofore, but did not produce results sufficiently comprehensive, due to the great differences in the quantity of water applied and to the lack of a complete analysis of the reasons for the results obtained.

The experiments to be described later were for the purpose of determining the duty of water for the propagation of certain wild grasses in Southeastern Oregon. They were confined to two localities, the valley of the Chewaucan River, in Lake County, and the valley of the Silvies River, in Harney County. In both localities, crops of wild or native grasses are raised for forage purposes, the raising of beef cattle being the main industry. Climatic conditions in these two regions are such that crops of greater value cannot be raised economically. Both regions are subject to long and severe winters, and, even in the summers, killing frosts frequently occur, no month of the year being free therefrom. Although some garden truck is raised for local use, and there are occasional patches of alfalfa and grain, the raising of any of these on a commercial basis is a hazardous undertaking. The raising of native wild grasses, however, inured to the existing climatic conditions, is very profitable, such grasses having good food value, and the cattle raised thereon being famous for their quality.

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* "Co-operative Investigations of Idaho."

† Reports for 1910, 1911, 1912, and 1913.

In the Chewaucan River Valley, Fig. 1, the river, on emerging from the mountains, flows on to a broad marsh, almost level transversely, and with a uniform fall longitudinally of about 1 ft. per mile. This marsh is divided into two parts by spurs of the mountain extending toward its center, leaving only a narrow channel between their extremities, through which the water passes from the upper to the lower end. This gives the marsh an hour-glass form, the area of the upper end being about twice as great as that of the lower, and the two parts being designated the Upper and Lower Marshes, respectively. In former years, the spring freshets emerging from the mountains and discharging on the upper end of the upper marsh, spread indiscriminately over it, inundating it for long periods; the waters were gathered together again at the Narrows and at the lower end of this canyon, and again spread on the lower marsh, which they inundated before being again gathered together and discharged into Lake Abert, about 4 miles below. These inundations caused the growth of many plants of a somewhat aquatic nature, some of which were valuable for the

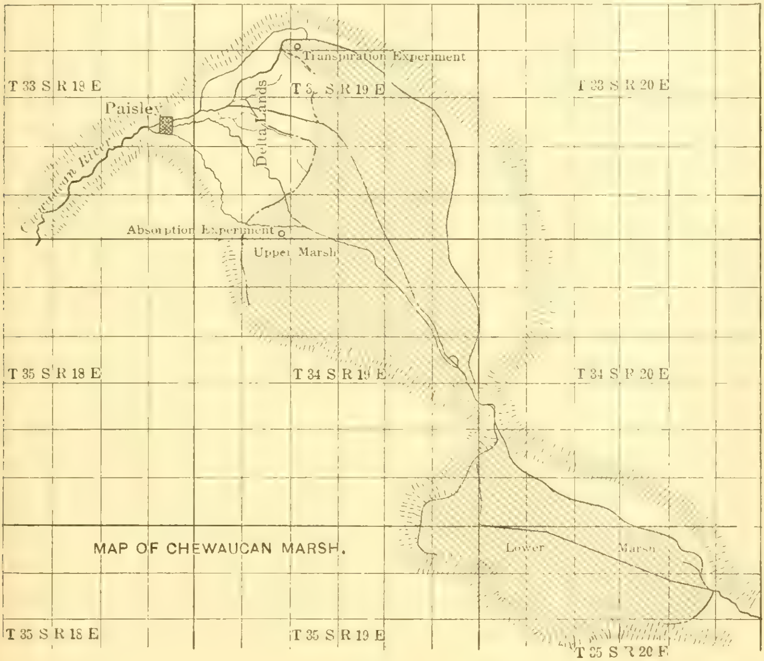

FIG. 1.

feed of animals and some of which were not. During the winter, this growth died down and was trampled by such stock as went on the marsh, so that a peat soil, from 1 ft. to several feet in thickness, has been built up. The nature of the inundations was such that full value could not be derived from the marsh for feeding purposes, on account of the likelihood of stock being trapped by freshets and lost by miring. The owner at that time, therefore, began to establish works for the purpose of controlling the water on the marsh and for facilitating drainage after the freshets ceased. These works have been amplified by successors in ownership, so that now there is quite a comprehensive system of works, designed to facilitate the even distribution of irrigation water and hold the freshet water off the marsh during such seasons as it would work injury rather than be beneficial for irrigation. The nature of the plants is such, due to the fact that they had their start under conditions of continuous flooding, that the same general method of applying water is still carried out. As will be described herein, however, the control of the water has caused an improvement in the nature of the plant growth, and will ultimately cause all the valueless plants to be replaced by those having a value for stock feed.

In the valley of the Silvies River (known as Harney Valley), Fig. 2, the river emerges from the mountains and splits up into various sloughs and branches, forming a delta over which the water has spread during times of freshet and annually causing the growth of certain wild grasses. Unlike the Chewaucan River, however, this is not a peat marsh, and the waters are not again brought together into one channel, but, after flowing over an area of considerable extent, are discharged into Malheur Lake. On account of the topography, the run-off is much more rapid, and the irrigation, consequently, is of shorter duration, so that the nature of the soil and of the crops is far different from those on the Chewaucan Marshes. To be sure, there are some pockets of small extent where conditions have been such as to cause the formation of peat layers and the growth of grasses similar to those on the Chewaucan Marshes, but, in the main, the growth is of a different nature.

Alkali.—In both the locations described, the valleys are surrounded by a volcanic formation locally known as the Rim Rock. The disintegration of the volcanic rocks releases alkaline salts, in greater or less quantities, so that, though the water itself carries a very low proportion of such salts, the soils—of considerable porosity and capillarity—have accumulated them to a large extent by absorbing their quota of the flood water and later giving up the free water therefrom by soil evaporation. This characteristic of the soil limits and determines the nature of the plant growth which can thrive thereon, and also prevents any form of irrigation which does not provide for carrying away the alkaline salts which otherwise accumulate on the surface.

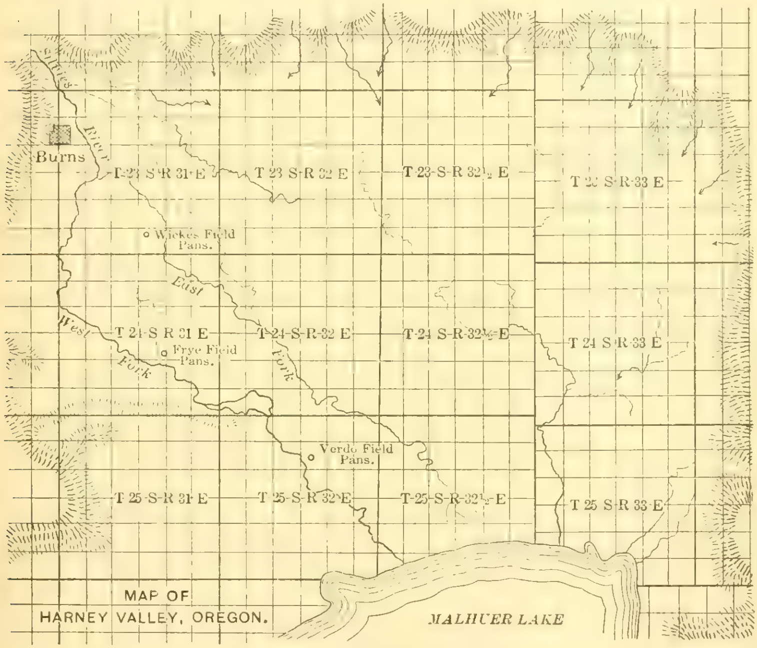

FIG. 2.

Chewaucan Marsh is underlain beneath the peat with a chalky substance which absorbs water with great readiness, but resists its passage to a large extent. The nature of the subsoil is such that it is continually saturated, but permits of little or no loss by deep percolation. Even in continuous droughts, the ground does not dry to a great depth, as the subsoil gives up its water reluctantly.

The soil on the uplands at the head of the Chewaucan Marshes, which uplands are really a fan-shaped delta over which the waters of the river originally spread before flowing to the marsh, is of a different nature. This soil is a fine, sandy loam, becoming more sandy with depth until the subsoil—of the same nature as that under the marsh—is encountered. In its general characteristics, the soil of the uplands above the Chewaucan Marsh is similar to that of Harney Valley.

Climate.—As already stated, the climate of Southeastern Oregon is very severe; winter lasts from October to March, the temperature often reaching many degrees below zero. The growing season is short, lasting only from April to September, and killing frosts are frequent in every month of the year. Two stations of the U. S. Weather Bureau are in the vicinity of Chewaucan Marsh, one at Paisley, 2½ miles above the marsh, and the other at Valley Falls, about 4 miles below it. The Weather Bureau station at Burns, Ore., at the head of the Harney Valley, provides data in regard to climatological conditions in that valley. For the purpose of indicating the nature of the climate in this vicinity, Tables 1 to 4 show the maximum, minimum, and mean temperatures for the stations at Paisley and Burns for a period of 11 years. Tables 5 and 6 show the maximum, minimum, and mean precipitation at the same stations for the same period of years.

TABLE 1.—SUMMARY OF MEAN MONTHLY TEMPERATURES NEAR PAISLEY. Compiled from U. S. Weather Bureau Records.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906..	33.2	33.1	35.8	47.0	51.1	55.6	71.4	66.5	58.6	48.5	38.1	36.8
1907..	27.0	42.4	37.4	48.4	52.9	55.8	65.4	60.2	55.5	52.0	....	....
1908..	32.0	36.0	39.8	48.2	48.2	57.6	71.3	66.3	59.8	47.0	41.8	28.2
1909..	35.6	37.4	40.5	46.8	51.0	60.4	64.4	66.4	50.3	50.7	41.2	27.0
1910..	28.0	33.2	46.2	53.2	57.9	59.2	69.6	65.4	56.5	50.8	38.8	34.0
1911..	30.8	27.3	42.0	44.6	48.7	61.4	77.5	....	53.8	47.0	37.8	30.4
1912..	37.0	40.2	38.6	....	....	59.6	....	....	....	....	....	31.6
1913..	28.4	31.2	37.8	45.2	....	57.3	63.6	65.8	57.6	49.0	44.8	27.9
1914..	....	....	....	44.2	54.4	58.5	67.0	67.3	54.8	47.6	....	21.0
1915..	30.4	34.4	42.6	48.0	48.6	57.1	63.8	70.8	56.0	51.5	36.4	....
1916..	24.0	39.0	42.2	45.7	46.6	56.0	62.5	65.6	58.3	46.6	31.8	27.1
Mean	30.6	35.4	40.3	47.1	51.0	58.0	67.1	66.0	56.1	49.1	39.2	29.3

Annual mean = 47.4.

Nature of Experiments.—As it was impracticable to segregate certain measured areas and determine their actual use of water, some other method had to be devised. After a careful study of conditions, the writer decided that the analytic method was probably the best, and would also lead to obtaining data which would be valuable in the determination of any changes of system which it might be desirable to make later for the purpose of improving irrigation conditions.

TABLE 2.—COMPARISON OF TEMPERATURES, FROM RECORDS OF U. S. WEATHER BUREAU STATIONS, NEAR PAISLEY AND AT VALLEY FALLS, OREGON.

JANUARY.

	PAISLEY			VALLEY FALLS.		
Year.	Maximum.	Minimum.	Range.	Maximum.	Minimum	Range.
1906	50	....	....	....	....	....
1907	52	9	....	....	....	....
1908	49	7	....	....	....	....
1909	54	10	....	....	....	....
1910	56	— 9	....	....	....	....
1911	54	10	....	....	....	....
1912	57	5	....	....	....	....
1913	53	— 1	....	....	....	....
1914	....	....	....	....	....	....
1915	48	9	27	53	— 3	41
1916	47	6	20	55	2	32
	57	— 9	....	55	— 3	....

FEBRUARY.

Year.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.
1906	53	15	....	....	....	....
1907	60	23	....	....	....	....
1908	65	15	....	....	....	....
1909	53	12	....	....	....	....
1910	57	0	....	....	....	....
1911	45	10	....	....	....	....
1912	55	21	....	....	....	....
1913	62	5	....	....	....	....
1914	....	....	....	57	11	....
1915	50	19	24	56	15	38
1916	56	19	26	63	19	41
	65	0	....	63	11	....

MARCH.

Year.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.
1906	60	— 3	....	....	....	....
1907	62	21	....	....	....	....
1908	67	19	....	....	....	....
1909	60	21	....	....	....	....
1910	67	23	....	....	....	....
1911	72	9	....	....	....	....
1912	60	21	....	....	....	....
1913	64	11	....	....	....	....
1914	....	....	....	75	13	....
1915	69	20	29	72	15	50
1916	71	12	38	78	15	49
	72	— 3	....	78	13	....

TABLE 2.—(*Continued*).

APRIL.

	PAISLEY.			VALLEY FALLS.		
Year.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.
1906	79	18	....	....	....	....
1907	71	23	....	....	....	....
1908	77	21	....	....	....	....
1909	70	24	......	....	....	....
1910	84	29	....	....	....	....
1911	70	18	....	....	....	....
1912	....	....	....	....	....	....
1913	72	22	....	....	....	....
1914	74	22	....	75	22	....
1915	78	25	40	82	20	50
1916	70	22	34	77	20	44
	84	18	....	82	20	....

MAY.

	PAISLEY.			VALLEY FALLS.		
Year.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.
1906	81	29	....	....	....	....
1907	83	31	....	....	....	....
1908	74	26	....	....	....	....
1909	85	26	....	....	....	....
1910	92	31	....	....	....	....
1911	77	26	....	....	....	....
1912	....	....	....	....	....	....
1913	....	....	....	....	....	....
1914	86	27	....	88	23	....
1915	78	25	37	81	14	44
1916	79	20	36	84	15	52
	92	20	....	88	14	....

JUNE.

	PAISLEY.			VALLEY FALLS.		
Year.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.
1906	80	34	....	....	....	....
1907	83	28	....	....	....	....
1908	86	32	....	....	....	....
1909	89	37	....	....	....	....
1910	91	32	....	....	....	....
1911	89	33	....	....	....	....
1912	87	34	....	....	....	....
1913	84	35	....	....	....	....
1914	95	29	....	93	25	....
1915	87	31	35	90	28	52
1916	89	30	39	93	25	51
	95	28	....	93	25	....

TABLE 2.—(*Continued*).

JULY.

	PAISLEY.			VALLEY FALLS.		
Year.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.
1906	92	50	....	....	....	....
1907	89	40	....	....	....	....
1908	95	48	....	....	....	....
1909	89	35	....	....	....	....
1910	95	42	....	....	....	....
1911	95	39	....	....	....	....
1912	....	....	....	....	....	....
1913	88	34	....	....	....	....
1914	93	40	....	96	33	....
1915	93	38	49	98	33	52
1916	91	36	40	94	29	55
	95	34	....	98	29	....

AUGUST.

Year.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.
1906	80	40	....	....	....	....
1907	87	33	....	....	....	....
1908	94	33	....	....	....	....
1909	93	41	....	....	....	....
1910	90	36	....	....	....	....
1911	....	....	....	....	....	....
1912	....	....	....	....	....	....
1913	91	35	....	....	....	....
1914	96	38	....	99	32	....
1915	97	49	39	102	40	57
1916	91	31	41	95	26	56
	97	31	....	102	26	....

SEPTEMBER.

Year.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.
1906	86	30	....	....	....	....
1907	86	33	....	....	....	....
1908	88	24	....	....	....	....
1909	84	26	....	....	....	....
1910	82	31	....	....	....	....
1911	81	35	....	....	....	....
1912	....	....	....	....	....	....
1913	88	27	....	....	....	....
1914	80	29	....	88	22	....
1915	82	32	34	90	20	52
1916	83	33	36	90	24	57
	88	24	....	90	20	....

TABLE 2.—(*Continued*).

OCTOBER.

	PAISLEY			VALLEY FALLS.		
Year.	Maximum.	Minimum.	Range	Maximum.	Minimum.	Range.
1906	80	23	....	....	....	....
1907	69	27	....	....	....	....
1908	76	19	....	....	....	....
1909	74	31	....	....	....	....
1910	78	30	....	....	....	....
1911	74	26	....	....	....	....
1912	....	....	....	....	....	....
1913	94	19	....	....	....	....
1914	72	30	....	85	19	....
1915	80	27	37	85	15	60
1916	74	24	32	75	10	53
	94	19	....	85	10	....

NOVEMBER.

Year.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.
1906	67	10	....	....	....	....
1907	....	....	....	....	....	....
1908	67	19	....	....	....	....
1909	65	11	....	....	....	....
1910	66	7	....	....	....	....
1911	58	14	....	....	....	....
1912	....	....	....	....	....	....
1913	67	19	....	....	....	....
1914	60	....	....	69	5	....
1915	57	14	26	71	12	48
1916	61	5	28	72	— 6	60
	67	5	....	72	— 6	....

DECEMBER.

Year.	Maximum.	Minimum.	Range.	Maximum.	Minimum.	Range.
1906	58	6	....	....	....	....
1907	....	....	....	....	....	....
1908	50	— 4	....	....	....	....
1909	50	2	....	....	....	....
1910	....	0	....	....	....	....
1911	50	10	....	....	....	....
1912	54	9	....	....	....	....
1913	50	10	....	....	....	....
1914	47	0	....	48	12	....
1915	....	0	....	58	— 9	40
1916	48	3	34	55	— 2	35
	58	4	....	58	—12	....

TABLE 3.—Summary of Mean Monthly Temperatures near Burns, Oregon.

Compiled from U. S. Weather Bureau Records.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906..	23.4	23.6	29.2	47.0	49.1	58.6	72.8	67.7	56.6	57.6	29.4	31.2
1907..	23.2	39.6	38.2	50.5	54.6	55.5	67.4	60.8	54.8	54.4	37.0	29.6
1908..	26.5	32.8	40.1	49.4	44.5	68.2	69.6	64.3	57.6	45.3	38.3	24.4
1909..	28.9	31.8	38.7	41.9	49.0	59.2	66.1	66.2	57.6	44.8	37.2	16.4
1910..	17.5	25.4	42.6	49.2	55.2	56.9	68.9	63.0	56.9	49.4	36.8	26.6
1911..	25.3	18.0	38.3	41.8	45.9	60.4	67.6	63.1	51.4	43.2	35.8	23.8
1912..	25.2	32.4	41.7	42.8	51.6	58.0	....	64.1	58.0	43.9	36.3	25.2
1913..	20.4	25.8	35.2	44.0	54.4	60.4	68.6	68.6	57.8	46.7	33.8	26.5
1914..	....	30.0	45.9	48.2	53.7	53.1	68.8	....	....	....	31.6	12.9
1915..	19.6	32.6	42.5	54.6	50.4	58.1	64.9	73.4	61.5	....	33.6	....
1916..	....	....	43.0	47.2	....	....	....	....	....	....	....	....
Mean	23.3	29.2	39.6	47.0	50.8	58.8	68.3	65.7	56.9	47.4	35.6	24.1

Annual mean = 45.6

The analytic method consisted in dividing the water into its various uses and making a separate determination, as far as possible, of each use. In this manner, any of the determinations which were based on estimates, or for which the data were inadequate or unreliable, would affect only the particular item concerned, and not the whole duty of water. Another advantage of this method of determination is that, by a study of the different factors making up the analysis, unnecessary or reparable losses may be discovered and the system improved so as to eliminate them.

In a strict sense, the only water actually used by a plant in its growth is that taken in through the roots and either remaining as a component part of it or being given off through its leaves by the process of transpiration. However, as it is impossible to deliver water to the roots directly, and as, even if it were possible to do so, it would be necessary to pass the water through the soil in order that it might take into solution the salts necessary for plant growth, there are various other uses which can be considered as beneficial to plant growth. Consequently, it may be considered that the various components into which the beneficial use of water is divided are as follows:

(1) Soil Moisture,
(2) Soil Evaporation,
(3) Plant Use,
(4) Soil Losses.

TABLE 4.—RANGE OF TEMPERATURE AT U. S. WEATHER BUREAU STATION AT BURNS, OREGON.

Year.	JANUARY.			FEBRUARY.			MARCH.			APRIL.		
	Max.	Min.	Range	Max.	Min.	Range.	Max.	Min.	Range.	Max.	Min.	Range.
1906	45	— 4	....	48	— 7	....	54	—12	....	70	24	....
1907	47	— 8	....	59	20	....	66	16	....	78	24	....
1908	46	8	....	65	9	....	66	12	....	80	18	....
1909	49	— 7	....	56	9	....	66	18	....	68	12	....
1910	46	—24	....	52	— 9	....	68	21	....	85	19	....
1911	50	— 9	....	39	7	....	79	7	....	70	12	....
1912	47	—21	....	49	6	....	71	13	....	72	20	....
1913	48	13	....	49	0	....	64	8	....	79	13	....
1914	..	3	....	54	— 1	....	74	14	....	74	23	....
1915	44	—20	38	47	9	30	72	14	45	85	24	60
1916	..	..	....	..	....	....	70	..	....	76	..	....
	50	—24	....	65	— 9	....	79	—12	....	85	12	....

Year.	MAY.			JUNE.			JULY.			AUGUST.		
	Max.	Min.	Range.	Max.	Min.	Range.	Max.	Min.	Range.	Max.	Min.	Range.
1906	81	25	....	90	31	....	97	42	....	96	37	....
1907	83	30	....	85	30	....	97	40	....	95	32	....
1908	76	25	....	88	30	....	100	38	....	96	27	....
1909	84	22	....	89	30	....	95	31	....	100	31	....
1910	97	28	....	94	25	....	100	37	....	95	33	....
1911	78	17	....	97	31	....	97	29	....	93	34	....
1912	80	25	....	89	29	....	..	36	....	100	25	....
1913	89	26	....	90	31	....	95	34	....	100	34	....
1914	86	26	....	86	26	....	96	34	....	94	40	....
1915	77	27	....	89	34	49	99	34	....	99	48	....
1916	..	..	....	..	..	....	..	..	....	..	..	....
	97	17	....	97	25	....	100	29	....	100	25	....

Year.	SEPTEMBER.			OCTOBER.			NOVEMBER.			DECEMBER.		
	Max.	Min.	Range	Max.	Min.	Range.	Max.	Min.	Range.	Max.	Min.	Range.
1906	87	26	....	84	16	....	58	— 2	....	50	5	....
1907	92	26	....	81	27	....	64	15	....	59	4	....
1908	92	17	....	79	19	....	66	9	....	41	— 2	....
1909	89	24	....	71	19	....	59	5	....	44	—11	....
1910	87	28	....	84	15	....	64	— 2	....	50	0	....
1911	90	19	....	66	17	....	61	6	....	54	— 6	....
1912	90	26	....	82	12	....	60	14	....	48	— 2	....
1913	89	26	....	72	16	....	70	10	....	52	— 1	....
1914	..	..	....	..	..	....	56	5	....	44	13	....
1915	91	33	....	..	..	....	58	— 4	40	..	....	....
1916	..	..	....	..	..	....	..	....	....	..	....	....
	92	17	....	84	12	....	70	— 4	....	59	—13	....

TABLE 5.—SUMMARY OF MEAN MONTHLY PRECIPITATION NEAR PAISLEY.

Compiled from U. S. Weather Bureau Records.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906....	....	....	....	0.44	1.11	0.55	1.03	0.94	0.15	0.89	0.75	0.89
1907....	1.03	1.67	2.65	0.09	1.62	2.80	0.30	0.50	1.35	0.88	....	....
1908....	0.34	0.58	0.11	0.21	0.95	0.56	1.07	0.44	0.40	1.42	0.41	0.30
1909....	2.60	0.55	1.02	T.	0.91	0.81	0.23	0.06	0.81	0.98	2.06	0.77
1910....	0.30	0.49	0.67	0.21	0.12	0.49	0.30	0.00	0.76	0.29	2.83	0.18
1911....	2.95	1.33	0.53	1.24	0.10	1.83	T.	....	1.31	0.45	0.14	T.
1912....	2.44	1.83	0.57	2.30	2.78	2.36	0.82	0.49	0.75	0.82	0.94	2.25
1913....	0.89	0.18	0.07	0.34	....	1.95	2.34	0.79	0.42	0.11	1.38	0.80
1914....	....	....	....	1.50	1.36	2.25	0.69	T.	1.59	2.51	0.51	0.39
1915....	0.60	2.89	1.51	1.02	1.72	0.23	1.56	0.06	0.08	0.57	2.54	2.46
1916....	2.46	1.35	2.21	1.35	2.83	1.53	0.42	0.40	0.61	0.08	1.67	1.54
Mean ..	1.51	1.21	1.04	0.79	1.35	1.40	0.80	0.37	0.76	0.82	1.32	0.96

Mean annual precipitation = 12.32.

TABLE 6.—SUMMARY OF MEAN MONTHLY PRECIPITATION NEAR BURNS.

Compiled from U. S. Weather Bureau Records.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906....	4.24	1.38	3.94	0.26	2.43	1.41	0.36	0.43	0.59	0.23	0.96	1.88
1907....	2.08	2.36	2.33	1.06	0.51	1.59	0.26	0.10	1.01	0.17	0.51	3.49
1908....	0.90	0.23	0.34	0.71	1.05	0.73	0.42	0.31	0.81	1.35	0.48	0.59
1909....	3.86	1.54	0.64	0.10	0.51	0.23	0.07	0.00	0.90	1.01	2.95	2.29
1910....	1.29	1.97	1.74	0.32	0.34	0.04	0.03	0.00	0.83	1.16	3.33	1.27
1911....	1.59	0.50	0.18	0.36	0.75	0.56	0.13	0.00	0.55	0.13	0.72	0.71
1912....	1.94	1.35	0.55	1.97	1.69	1.17	0.91	0.44	0.61	0.16	1.66	1.19
1913....	1.55	0.15	0.86	0.99	0.25	2.93	1.99	0.19	0.15	1.63	1.08	2.05
1914....	2.52	0.80	0.15	1.49	0.94	1.41	0.00	0.00	....	....	0.03	0.42
1915....	1.06	1.60	0.90	1.18	0.94	0.40	0.90	0.06	0.04	....	1.26	....
1916....	....	....	0.38	0.44	....	....	....	....	....	....	....	....
Mean ..	2.10	1.18	1.09	0.80	0.94	1.04	0.50	0.15	0.61	0.73	1.29	1.54

Mean annual precipitation = 12.01.

(*1*).—*Soil Moisture.*—The necessary soil moisture differs in different cases. Some plants require a soil having little more than hygroscopic moisture; from this minimum the requirements of various plants increase through all gradations, some even requiring a saturated soil with free surface water. Among the latter, the most widely known is rice.

(*2*).—*Soil Evaporation.*—As water cannot be brought through the soil to the roots of plants without a certain proportion being drawn to the surface by capillarity and thence evaporated, soil evaporation may be considered as a beneficial use. This evaporation will vary according to the method of irrigation and the nature of the plant—deep-rooted plants irrigated by sub-surface application requiring very little soil evaporation, and those which must have a saturated soil and free surface water requiring a very high evaporation.

(*3*).—*Plant Use.*—Plant use consists of the water going into the plant structure and that given off by transpiration through the leaves. The first is negligible when compared with the other components. Transpiration, however, is one of the most important uses of water.

(*4*).—*Soil Losses.*—Certain losses in the application of water are necessary, for various reasons: Few subsoils permit of the application of water by any of the irrigation methods in general use without deep percolation or subsoil losses. The nearer to saturation the soil is required to be, the greater will be the underground losses. Where free water is required on the surface, a certain quantity of this must be drained off, in order that continuous evaporation will not cause the concentration of the injurious salts carried. In some cases, a movement of water is also required in order to avoid the loss of air from the water and the consequent stagnation which is injurious to such plants. This movement necessarily entails an additional loss, that of run-off.

To the foregoing may also be added delivery losses in bringing the water to the land. In this paper, however, these losses are not considered, as the duty of water is here treated as the net duty on the land, and not the gross duty from the point of supply.

The growth on the Chewaucan Marshes consists of certain grasses of local importance which are little known in other parts of the country. The most valuable of these are the "Awned Sedge" (*Carex Aristeta*) and "Sprangle Top" (*Scholochloa Festucacea*). There is very little literature on these two grasses, and their habitat seems to be extremely limited. Both occur only in severe climates, no examples being known south of the forty-second parallel of latitude, and they are found on the North American Continent only in Canada and some of the most northerly parts of the United States. They grow in profusion in a few places in Oregon, and all that have been examined seem to require a peat soil and conditions of inundation during the growing season. Apparently, a distinct movement of the water is also necessary, as any check in the flow seems to cause a replacement of these grasses by tules, cat-tails, and other waste growths which thrive

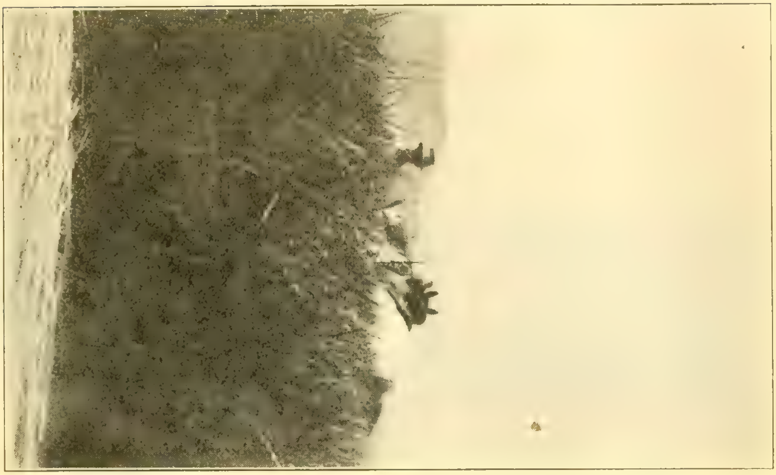

FIG. 3.—NORMAL GROWTH OF SUGAR GRASS.

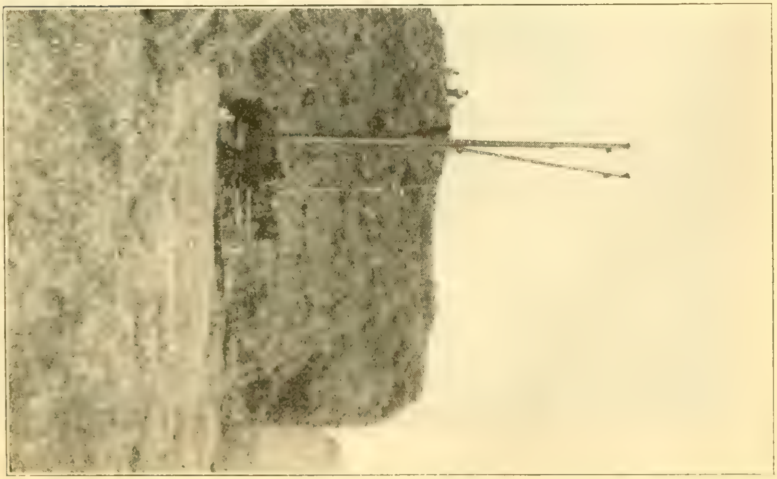

FIG. 4.—STACKING SUGAR GRASS HAY.

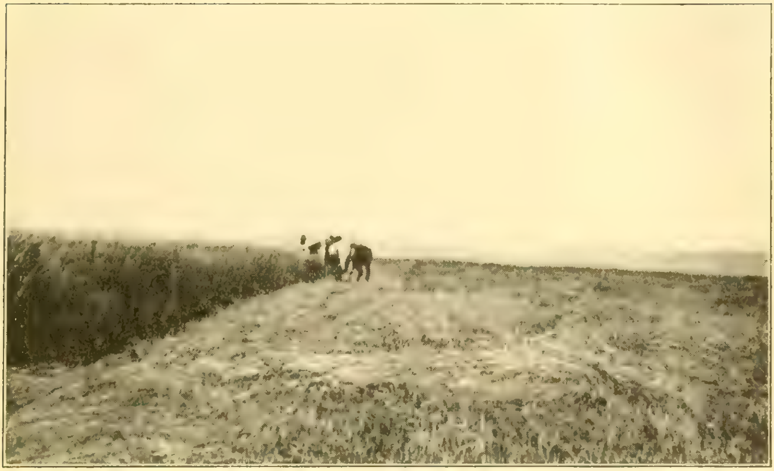

FIG. 5.—FIELD OF SUGAR GRASS DURING CUTTING.

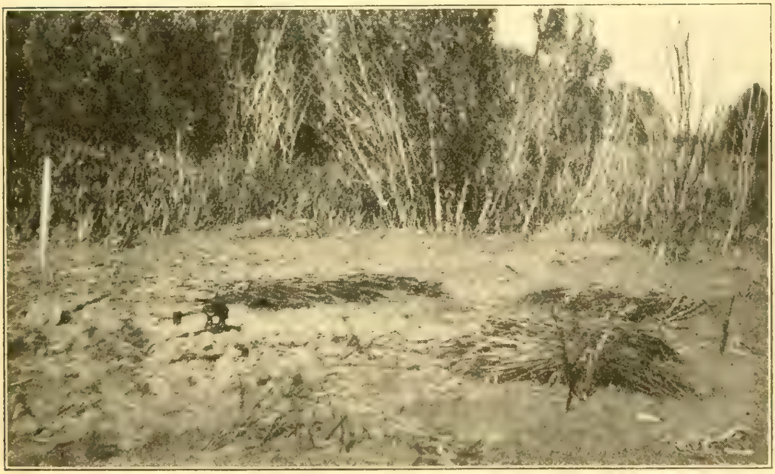

FIG. 6.—TRANSPIRATION EXPERIMENT BY CUTTING.

in still or stagnant water. Where conditions are right, in regard to the period of inundation and the flow of water, and where the soil is a true peat, the plants attain a height of from 4 to 8 ft., cutting from $2\frac{1}{2}$ to 5 tons of cured hay to the acre. Where water is plentiful, and the inundation is continuous during the growing season, neither of these grasses flowers, but the growth goes entirely to stalk and leaf. In this condition, the appearance of both kinds is very similar, so that only a person familiar with the characteristics of the two plants is able to distinguish one from the other. They are locally known as "Sugar Grass", the term being applied indiscriminately to the two varieties. The two occur sometimes in mixed patches, and sometimes in patches containing only one of the varieties.

Where the water supply fails before the culmination of the growth of these plants, and where such plants reach maturity under conditions of a moist soil, instead of a saturated soil with surface water running over it, they sometimes go to seed, particularly the Sprangle Top. This condition obtains on various high knolls which do not receive as much water as the remainder of the marsh, and the appearance of the plant in flower is so different from that before flowering that it has been popularly supposed to be of a different variety, and is locally known as "Rice Grass".

There have been no exact experiments to determine the food value of the plant, either by feeding to stock or by analysis of the hay. Among the ranchers conversant with this subject, however, it is generally conceded that, pound for pound, Sugar Grass hay is equal to Alfalfa for the fattening of beef-cattle. There is a difference of opinion as to its value for feeding work stock, some holding that work horses hold up slightly better on Timothy hay, and some claiming that Sugar Grass hay is equal or superior to Timothy hay for work stock as well as beef-cattle. The fact remains, however, that the company operating the marshes feeds more than 10 000 head of cattle for 5 winter months on 20 lb. of Sugar Grass hay per day per animal, bringing them out in the spring in much better condition than they were when they went in in the fall, and also that, during the harvest season, both the cow-ponies and the draft animals on the harvesting machinery are worked under extremely severe conditions on a diet consisting only of Sugar Grass hay, without a pound of grain, which shows that the food value is excellent.

The vegetation in Harney Valley consists of a miscellaneous growth of wild or partly wild grasses. A large part of the land was seeded in the past to Timothy and Red-top, and traces of these grasses remain throughout much of the valley. Mixed with them, however, on the sedimentary soils, are found "Nevada Blue Grass", "Soft Leaf Sedge" and other less valuable wild grasses. Where peat soil occurs, heavy growths of "Sugar Grass" are found.

TEMPERATURE-EVAPORATION CURVES
FOR EXPERIMENTS NEAR INDEPENDENCE, CAL.,
AND AT ADY, OREGON,
CORRECTED TO ELEVATION 4410.

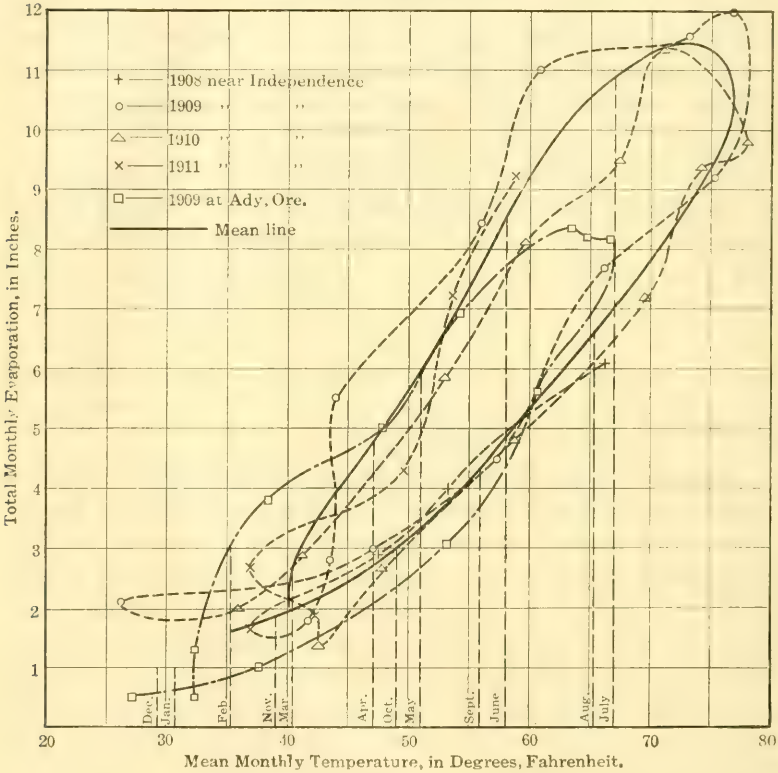

FIG. 7.

Evaporation.—Very few evaporation measurements have been taken in Oregon, and the conditions attending these investigations have been such as to make it impossible to carry on continuous experiments through all parts of the year. Continuous evaporation experiments, however, have been made in various places in California, and those in Owens Valley by C. H. Lee, M. Am Soc. C. E., during the period from 1908 to 1911, under the auspices of the Los Angeles Aqueduct Commission and the U. S. Geological Survey,* were taken as most nearly conforming to conditions as they occur in Eastern Oregon. The elevation of Owens Valley above sea level at the point where the Lee experiments were undertaken is 3 735 ft.; the elevation of Chewaucan Marsh is approximately 4 410 ft. Temperature conditions for Chewaucan Marsh are shown by Tables 1 and 2; those for Owens Valley were obtained in a similar manner from the records of the U. S. Weather Bureau.

The method of deducing the evaporation for the various months from free water surface near Paisley is shown by Fig. 7. In order to understand this matter thoroughly, a few preliminary points should be discussed.

The measurements of evaporation in Owens Valley were corrected for altitude in the inverse proportion which the barometric heights in the two places bore to each other. Although it has never been proved, academically, that evaporation at different elevations is in inverse proportion to the barometric pressure, the writer's observations have always led him to believe this to be a fact. Relative to this matter, it is interesting to note that, in the paper entitled "A Study of the Depth of Annual Evaporation from Lake Conchos, Mexico",† by Edwin Duryea, M. Am. Soc. C. E., and H. L. Haehl, Assoc. M. Am. Soc. C. E., about a year after the experiments described in this paper, the authors tabulate the results of all evaporation measurements throughout a broad area in the Southwestern United States and Northern Mexico in order to show the effect of elevation, and this tabulation shows indubitably that it is as above stated.

For a barometric height of 30 in. at sea level, that at Elevation 3 775 would be 26 in., and that at Elevation 4 410 would be 25.35 in., from which it is seen that the evaporation at Elevation 4 410, all other conditions being equal, would be 16% greater than that at Elevation 3 775.

Professor Frank H. Bigelow and others have done considerable investigatory work to determine the relation between the evaporation from pans of various diameters and from lake surfaces. In the writer's experiments no consideration has been given to the possible lesser evaporation from a lake surface than from the pans used by Mr. Lee, due to the fact that conditions of cover were such as to make the evaporation more nearly conform to that found in pans than to that of a broad, uninterrupted lake surface.

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* Published in *Water Supply Paper No. 294*.

† *Transactions*, Am. Soc. C. E., Vol. LXXX, p. 1829.

In comparing the evaporation in Owens Valley with that in the places covered by this investigation, allowance must be made for differences in humidity. Although no data are obtainable as to the relative humidity in the two locations, observation on the ground and a study of the topographical conditions enables one to make an approximate allowance. The Chewaucan Marsh is enclosed by high bluffs which protect it, more or less, from the action of the wind, and cause the humidity during times of flood to be higher than in broad valleys like those of the Owens and Silvies Rivers, the latter two being somewhat similar in configuration, and humidity conditions being more nearly the same. Moreover, the growing season in the Owens River Valley is longer than in Oregon, but the proportion of flooded land is very much smaller, which would tend to make the humidity, during the early months of the year and also during the summer, higher in the Owens Valley than in the Oregon valleys.

On Fig. 7 is platted a curve in which the abscissas represent the mean monthly temperatures, in degrees, Fahrenheit, and the ordinates the total monthly evaporation, in inches, for each month from September, 1908, to May, 1911, corrected for difference in elevation between 3 775 and 4 410 ft. From this, a mean curve is constructed, shown by the full line. In Table 9 are given, first, the results of applying the mean monthly temperatures near Paisley to this curve and getting the corresponding evaporation by intersection with the mean curve; second, the assumed mean monthly evaporation near Paisley after making corrections for the difference in local conditions; and third, the monthly evaporations obtained by intersecting the curve deduced from evaporation measurements at Ady, Ore., by the mean monthly temperatures for the station near Paisley. The latter evaporation measurements were taken under the direction of the U. S. Weather Bureau, in 1909, at Ady, Ore., near Klamath Lake, at an elevation of 4 090 ft., and the curve platted on Fig. 7 is deduced from these measurements, correcting for the difference of elevation by increasing the

TABLE 7.—MONTHLY EVAPORATION RECORD NEAR INDEPENDENCE, CALIFORNIA.

Elevation 3 735. 3-Ft. Square Pan.

Month.	1908		1909		1910		1911	
	Evaporation.	Mean temperature.	Evaporation.	Mean temperature.	Evaporation.	Mean temperature.	Evaporation.	Mean temperature.
January....	......	... ..	1.60	41.7	1 75	35.6	1.65	42.4
February	..... .	.. ..	2.40	43.6*	2.50	41.4	2.35	36.7
March.	......	......	4.70	44.2	5.15	53.2	3.70	49.8
April....... ..	......	......	7.30	56.0	7.05	59.8	6.25	53.6
May......... .	.... ..	......	9.60	60.8	8.29	67.5	8.01	58.7
June	......	......	10.10	73.0	9.90	71.0*	....	......
July	......	......	10.40	76.6	8.50	77.9	....	......
August.... .	......	......	8.00	75.3	8.20	74.2*	....	......
September .	5.30	66.2	6.60	66.2	6.30	69.7	....	......
October	3.50	53.4	3.90	57.3	4.20	58.6	....	.... ..
November...	2.50	47.2	2.60	47.0	2.36	48.0	....	......
December....	1.50	36.6	1.85	26.0	1.24	42.4*	....	.. ...
Totals.........	. ....	......	69.05	55.6	65.44	58.3	....	...

Evaporation from Water Supply Paper No. 294.

Temperature from Weather Bureau records at Independence.

* Record at Lone Pine.

TABLE 8.—MONTHLY EVAPORATION RECORD AT ADY, OREGON.

Elevation, 4 090. 4-Ft. Cylindrical Pan.

1909.

Month.	Evaporation.	Mean temperature.
January.................	0.50*	32.2+
February............................	1.25*	32.5+
March..................................	3.57*	38.4+
April....................................	4.64	47.7
May..................	6.48	54.2
June	7.78	63.6
July......................................	7.65	64.6
August.................................	7.64	66.6
September	5.26	60.5
October................................	2.87	53.2
November.............................	1.00*	37.5†
December.............................	0.50*	27.0†
Totals......................	49.14	48.2

* From Moritz's "Working Data for Irrigation Engineers."

+ From Weather Bureau records at Klamath Falls.

Other data from Weather Bureau records at Ady, amplified by interpolation for missing days.

TABLE 9.—EVAPORATION FROM WATER SURFACE NEAR PAISLEY, OREGON.

Elevation, 4 410.

Month.	Mean monthly temperature.	Monthly evaporation, from chart.	Monthly evaporation, assumed.	Monthly evaporation, from Ady line.
January	30.6	No intersection.	1	No intersection.
February	35.4	" "	1	2.9
March	40.3	2.9	2	4.1
April	47.1	4.7	3	4.9
May	51.0	5.9	4	5.7
June	58.0	8.4	7	7.6
July	67.1	10.8	8	8.2
August	66.0	6.6	7	7.1
September	56.1	4.3	5	3.7
October	49.1	3.0	3	2.4
November	39.2	1.9	1	1.2
December	29.3	No intersection.	1	0.6
Totals	47.4	....	43	....

evaporation measurements 7½ per cent. These measurements were not available at the time the original computations were made, but, on making use of them, at present, it is interesting to note how closely they conform to the evaporation assumed, and how well the variations from the assumed ones are accounted for by the equalizing influence of Klamath Lake.

Having obtained the evaporation from the water surface by use of the diagram, Fig. 7, it was necessary to reduce this to the condition ot evaporation from a thin sheet of water passing over the soil and to conditions of protection by plant growth.

The first correction was made by adding 33% to the evaporations obtained, as described for the water surface, as investigators have found that the evaporation from a thin sheet of water is greater than that from an ordinary water surface, varying between 25 and 37 per cent. As for the plant protection, conditions are such, due to the close growth of the plants, that the humid air is held impounded by their leaves without being swept away by the wind and replaced by dry air, thus making the evaporation lower than it would be for an unprotected water surface. In these experiments, therefore, it was assumed that the evaporation from a field containing fully developed plants would be only one-third of that from the same field without vegetation. The ratio of evaporation, therefore, was assumed to drop uniformly from its full quantity at the beginning of the growing season to one-third of that quantity at the end of that season, and the evaporation above determined was corrected in this manner. Therefore, the evaporation is corrected to conditions of plant cover, as follows:

March 15th to 31st	1.33 in.
April	3.11 "
May	2.96 "
June	3.11 "
Total	10.51 in.

In the Harney Valley analysis, time was available for more complete experimental work than was done on the Chewaucan Marshes. Pan experiments were made in order to determine evaporation in connection with transpiration, and, as the records of soil evaporation were thus directly determinable, no analysis was made for this valley by comparison with distant data.

The pans used for evaporation tests were 11.3 in. in diameter, and 4 ft. deep, having a surface area of 100 sq. in., and a soil depth of 3 ft. inside the pan. The pans were sunk in the soil to a depth of 3 ft., and the soil was replaced inside them in the same order as it was taken out of the pit, all vegetation, however, being removed from the surface in order that the record of the pan would give the soil evaporation without being affected by transpiration. The diameter of the pan appears to be a trifle small, but it was constructed in that way in order that its surface would receive, as nearly as possible, the same protection as the surrounding soil. A gauging well of small diameter was put in the pan in order that the depth to ground-water could be determined at intervals. Observations were made every few days, and enough water was added to bring the ground-water elevation to the same height as that in the natural soil outside the pan, the water being measured into the pan to replace evaporation losses.

At the end of the test, at harvest time, enough water was added to bring the ground-water level to the same height as that at the beginning of the test, the total water added thus equalling the evaporation during the period of the tests. The results are shown graphically on Figs. 15 to 20.

Transpiration.—One of the most important processes by which plants achieve their growth is that known as transpiration. The structure of the leaves is such that their surfaces are covered with small openings or spores known as "stomata." Both surfaces are covered with these stomata, but the under surface has three or four times as many as the upper. Through these stomata the carbon from the air is admitted to the plant, and by a process in which sunlight forms an important part, this carbon, in combination with the water, is converted into starch, which forms a large part of the structure of many plants, particularly forage plants. The water taken in through the roots and flowing upward through the veins of the plant is evaporated from the surface of the leaves, serving to keep them moist and to operate the stomata, causing them to open or close and to regulate the quantity of air admitted, according to the requirements of the plant. This process has been described in various botanical and irrigation works,* and need not be mentioned herein. The quantity of water given off, however, is proportional to the quantity of starch produced by the plant and, consequently, to the growth of the plant itself, and the ratio of the quantity of water transpired to the quantity of plant matter produced, though not absolutely constant for certain plants, is within such close limits as to be to a certain extent measurable.

The quantity of transpiration, or the transpiration ratio, has been considered of such importance by scientists that many experiments have been made to determine it for many of the most common crops, particularly grains. Much valuable matter was contributed in this regard by the experiments of the University of Minnesota, prior to 1909, published by A. W. Sampson and L. M. Allen.† These studies showed the great effect of light on the quantity of transpiration, the lesser effect of heat, and the practically negligible effect of humidity. Fig. 8, reproduced from the "Minnesota Botanical Studies", shows the relations between the different phenomena mentioned.

Many other experiments have been made with soil pans in which plants are raised, the transpiration being measured by weighing the pan from time to time with its contents and weighing also the water applied, thus computing the water lost by transpiration. Descriptions of these experiments have been given in many scientific works and textbooks.* The determination in this manner, however, requires rather an elaborate experiment station and the constant attention of the observer.

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* Such as King's "Irrigation and Drainage."

† "Minnesota Botanical Studies", Part 1, Vol. 4.

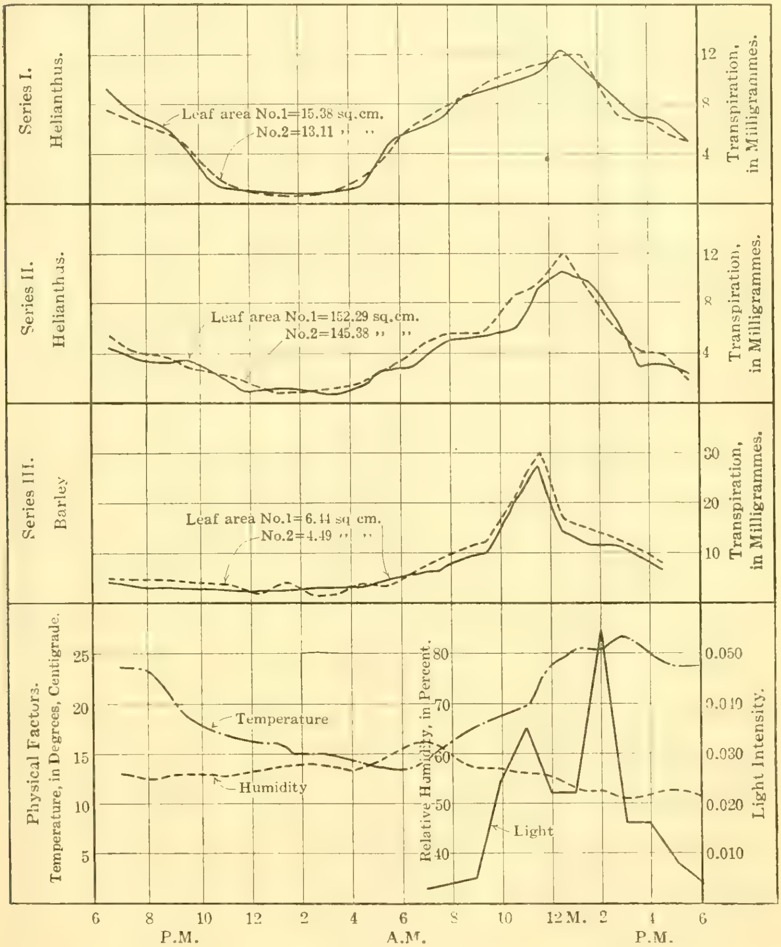

FIG. 8.

The transpiration ratio, or the relation of the quantity of water lost by transpiration to the quantity of dry matter produced for various crops, is shown in Table 10, taken from the work of Professor Fortier.

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* Among these are "Irrigation and Drainage", by F. H. King; "Use of Water in Irrigation", by Samuel Fortier, M. Am. Soc. C. E.; and "Principles of Irrigation Practice", by John A. Widtsoe.

TABLE 10.—TRANSPIRATION FOR VARIOUS STANDARD CROPS.

From "Use of Water in Irrigation", by Samuel Fortier.

Crop.	Location.	Experimenter.	POUNDS OF WATER PER POUND OF DRY MATTER.		
			Max.	Min.	Mean.
Wheat	Germany.	Sorauer.	708	....	708
	Germany.	Hellriegel.	390	328	339
	Germany.	Von Seelhorst.	333	....	333
	India.	Leather.	544	....	544
	Akron, Colo.	Briggs and Shantz.	534	468	507
	England.	Lawes.	235	....	235
	Logan, Utah.	Widtsoe.	489	427	458
	Davis, Cal.	Fortier and Beckett.	359	286	326
	Bozeman, Mont.	Fortier and Gieseker.	334	226	271
	Reno, Nev.	Fortier and Peterson.	395	309	360
Oats	Germany.	Wollny.	....	....	665
	Germany.	Sorauer.	....	....	600
	Germany.	Hellriegel.	464	339	401
	India.	Leather.	....	....	469
	Wisconsin.	King.	526	502	514
	Akron, Colo.	Briggs and Shantz.	639	598	614
Barley	England.	Lawes.	262	258	260
	Germany.	Wollny.	....	....	774
	Germany.	Sorauer.	....	....	490
	Germany.	Hellriegel.	366	263	297
	Germany.	Von Seelhorst.	454	295	365
	India.	Leather.	....	....	468
	Wisconsin.	King.	401	375	388
	Akron, Colo.	Briggs and Shantz.	544	527	539
Corn	Germany.	Wollny.	....	....	233
	India.	Leather.	....	....	337
	Wisconsin.	King.	390	305	348
	Akron, Colo.	Briggs and Shantz.	420	319	369
Rye	Germany.	Hellriegel.	438	315	377
	Germany.	Von Seelhorst.	700	343	469
	Akron, Colo.	Briggs and Shantz.	....	....	724
Peas	England.	Lawes.	....	....	235
	Germany.	Wollny.	....	....	416
	Germany.	Hellriegel.	353	231	292
	India.	Leather.	....	....	563
	Wisconsin.	King.	....	....	477
	Akron, Colo.	Briggs and Shantz.	....	....	800
Potatoes	Germany.	Von Seelhorst.	294	268	281
	Wisconsin.	King.	....	....	423
	Akron, Colo.	Briggs and Shantz.	....	....	448
Alfalfa	Davis, Cal.	Fortier and Beckett.			
1st year			1 265	1 005	1 102
2d year			971	522	761
	State College, N. Mex.	....	889	757	823
	Akron, Colo.	Briggs and Shantz.	....	....	1 068
Clover (red)	England.	Lawes.	....	....	251
	Germany.	Hellriegel.	363	297	330
	Wisconsin.	King.	564	398	481
Sugar beets	Logan, Utah.	Widtsoe.	....	....	497
	Akron, Colo.	Briggs and Shantz.	....	....	377
Rice	India.	Leather.	....	....	811

In describing experimental work done and deductions therefrom in connection with the water supply for Los Angeles, Cal.*, Mr. Charles H. Lee advances the theory that, if plants are cut, the water supply from their roots thus being instantly stopped, the transpiration will continue from the stored water in the plants for a brief period at the same ratio as before they were cut. Acting on this theory, Mr. Lee made some experiments with alfalfa, using 15 min. as the period for which transpiration would remain constant.

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* *Water Supply Paper No. 294,* U. S. Geological Survey.

In connection with the determination of the duty of water described herein, the writer made some experiments on the Chewaucan Marsh in order to determine the transpiration from sugar grass, following Mr. Lee's theory, and, though in doubt as to the maximum period for which transpiration will continue to be constant, he used 15 min. as the time, the same as Mr. Lee. It is interesting to note that, in experiments by pan methods, described later, the results are not incongruous as compared with the more accurate experiments made subsequently. Fig. 9 shows graphically the loss at various hours of the day, from the growing plants, in percentage of the green weight of the cut plants.

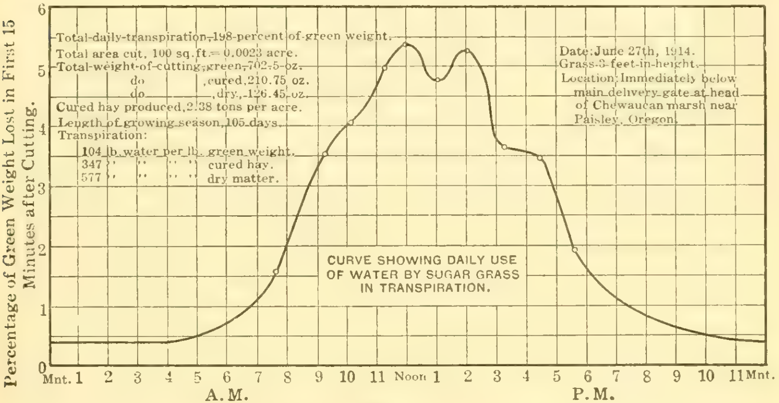


FIG. 9.

This experiment was performed by taking a typical growth of sugar grass of considerable extent, where the distribution of the plants was uniform, and laying this plat off in squares containing 10 sq. ft., each. From each of these squares the sugar grass was cut, and was weighed immediately on cutting and 15 min. later, the loss in weight for this time being computed as a proportion of the green weight at the time of cutting. Immediately after the first weighing, the plants were spread on a canvas and made to cover the same area as while standing; they were left in this position until the time of the second weighing. Fig. 6 shows the apparatus used for this purpose, which consisted of a scale, weighing accurately to half ounces, up to a maximum of 4 lb.

The result of this experiment showed the total transpiration for the day as 198% of the green weight of the plant at that period of its growth. As the plant was then full grown, it was considered that the green weight would vary uniformly from the time that it sprouted to the time when it had atttained its full growth, which would be from about March 15th to June 30th, or about 105 days. This would make the total transpiration during the growth of the plant 104% of its green weight at the time of cutting, or 104 lb. per pound of green weight at the time of cutting. Fig. 10 shows the loss of weight of the green cutting in curing for hay. It was found that after 3 days in ordinary weather the curing was complete, and the loss was approximately 70% of the green weight at the time of cutting.

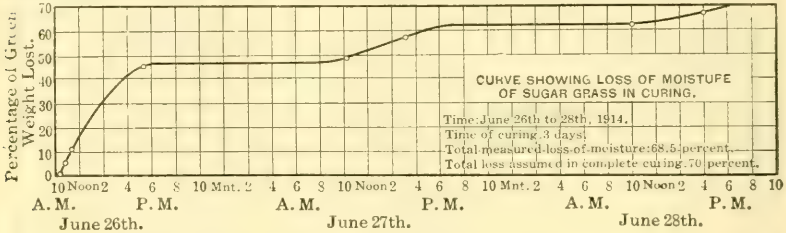


FIG. 10.

This would make the quantity of water transpired per pound of cured hay, 347 lb. It was also found that the cured hay contained about 40% of water; consequently, the transpiration per pound of dry matter would be 577 lb. This, however, is merely given for purposes of comparison with tables of transpiration for other plants which are reduced to a basis of dry matter produced, because, for the purpose of the experiments, the comparison was required with cured hay. Experiments were also made to ascertain whether or not the loss of weight was uniform for the first 15 min., and consequently equal to the transpiration rate. Although the experiments seemed to show that the rate of loss immediately after cutting was from 40 to 50% greater than after a period of 15 min., the chance of error in such small periods of time was considered great enough to warrant the experimenters in ignoring this result.

In the determination of the duty of water in Harney Valley, the experiments were more elaborate. As stated previously, the growth in

Harney Valley consists of various kinds of plants, and, consequently, experiments were conducted to show the transpiration for several kinds of growth, as follows:

Each experiment required an equipment consisting of three soil pans. Two of these were 35.7 in. in diameter and 4 ft. in depth, sunk 3 ft. into the soil, and having the excavated soil replaced in the pan in the same order as it was taken out, so that the top of the soil in the pan consisted of an unbroken sod containing the same growth as the remainder of the field. The third pan was 11.3 in. in diameter, 4 ft. in depth, sunk to the same depth as the other pans, and having the soil replaced therein in the same order, with the exception that all vegetation and plant growth were carefully removed, so that the pan would serve for soil evaporation only. As will be noted, the surface area of the two large pans was 1 000 sq. in. each, and that of the small pan was 100 sq. in. The evaporation pan was made of less diameter in order to maintain as nearly as possible the same conditions of shaded area as occurred in those pans covered with plant growth. Rain gauges were also maintained in connection with each set of pans, in order to take account of the precipitation during the period of the experiment.

At the beginning of the irrigation season, sufficient water was measured into each pan to bring the ground-water level therein to the same elevation as that in the soil of the field itself. Thereafter, observations were made at periods of from 4 to 10 days, and sufficient water was measured into each pan at each observation to keep the level at the same elevation as in the remainder of the field. A record was kept of the quantity of water introduced into each pan, the elevation of ground-water referred to the bottom of the pan, and such other data in regard to the growth of plants, the rainfall, and other conditions, as would aid in analyzing the results. At harvest time, sufficient water was introduced to bring the ground-water to the same elevation as that at the beginning of the test, the total water added thus equalling that used by the plants in transpiration plus the soil evaporation. In the final analysis of the duty of water, these two items were not segregated, but the total used in each pan was charged against transpiration and evaporation. For purposes of comparison with other transpiration data, however, the evaporation pan was used as a control, and the evaporation from it was deducted from the total in the other pans, in inches of height, the difference being considered as transpiration. It is not claimed that this will give absolutely accurate results as to transpiration, for the reason that conditions in the evaporation pan, on account of absence of mulch due to growing sod, will be somewhat different from those in the transpiration pans, but, as the area of the evaporation pan was made small enough so that the adjacent growth would protect the surface practically to the same extent as in the large pans, the results would be sufficiently close to give an approximation to the transpiration. Whatever inaccuracies might occur in the calculation of either evaporation or transpiration were eliminated by the use of the results from this pan as a combined figure for evapo-transpiration.

Figs. 15 to 20 show graphically the mass curve of the quantity of water added to each pan, exclusive of that added at first to bring ground-water to the starting elevation, and the fluctuation of ground-water in the pan during the period of the test. The tests covered the irrigation seasons of 1915 and 1916, and are interesting in showing the difference of conditions during the two seasons, there being a corresponding difference in evaporation, but a close agreement in transpiration ratio, as would be expected. The year 1915 was extremely dry, and the flood came down somewhat later than usual in the summer, which caused the length of the growing season to be very much less than its average, due to shortening both at the beginning and at the end. The season of 1916, however, was an extremely good one for irrigation, although the mean temperatures ran somewhat below the 11-year mean for which records are available.

In converting the transpiration ratio, as determined by these experiments, to the actual duty of water chargeable to transpiration, in acre-inches, the growth had to be estimated. Experiments were made in various localities as to the weight of the green cutting and the consequent hay produced; but, in order to use the data throughout the localities in question, average crop figures had to be utilized. Although the different experiments showed from 3 to 5 tons per acre of hay harvested from the Chewaucan Marsh, and from 2 to 5 tons from the Harney Valley fields, an inspection of crop reports showed that the average quantity produced from the former locality was slightly less than 3 tons per acre, and that harvested from the latter

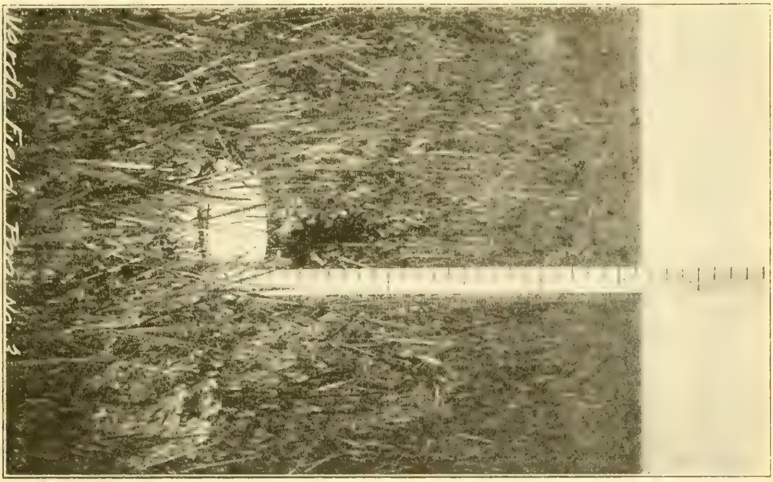


Fig. 11.—Soil Evaporation Pan.

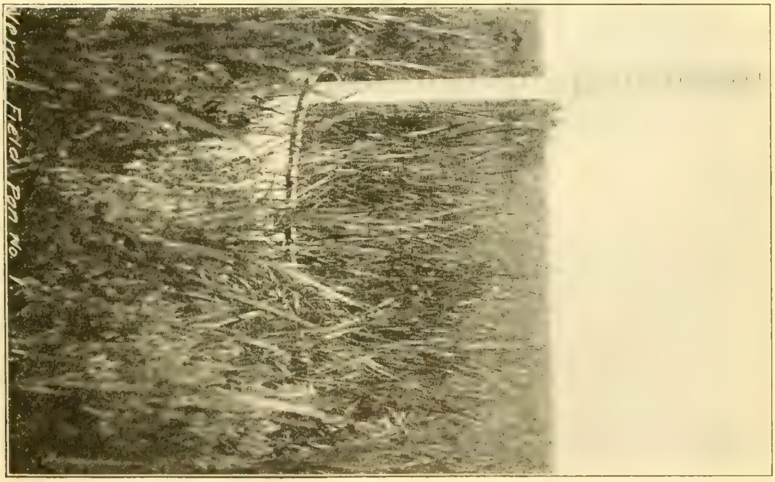


Fig. 12.—Transpiration Pan.

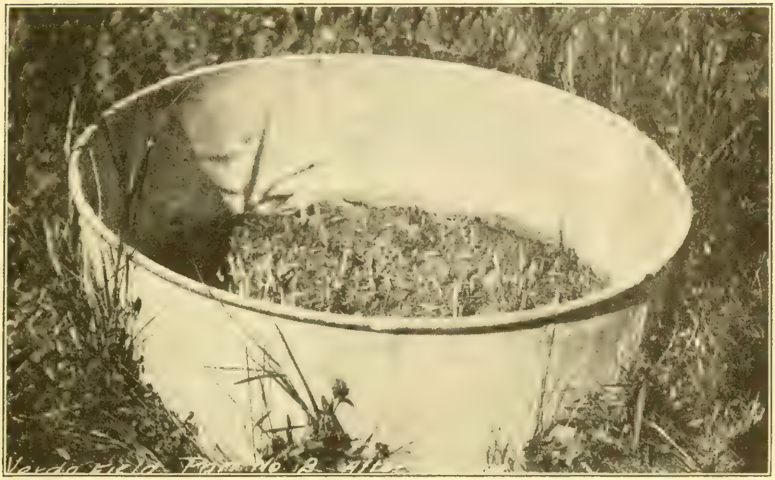


FIG. 13.—ONE OF THE TRANSPIRATION PANS AFTER HARVESTING THE CROP.

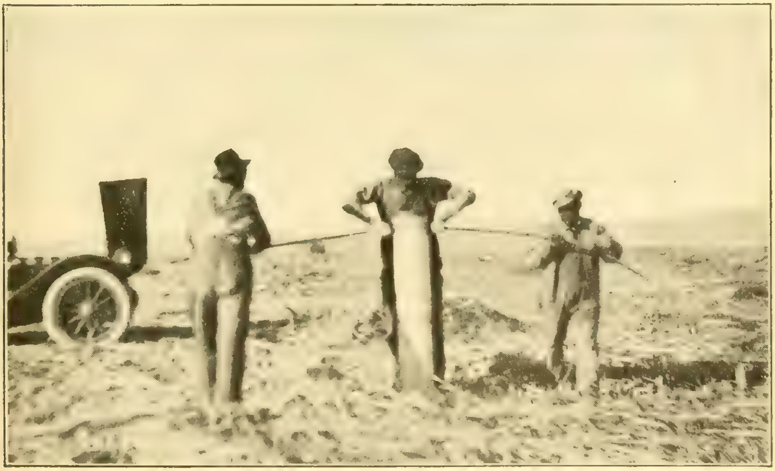


FIG. 14.—SINKING TUBE THROUGH SOD BY TURNING.

locality was but little more than 1 ton per acre. Therefore, in converting the figures of transpiration to acre-inches, a crop intensity of 2½ tons per acre was used for the Chewaucan Marsh, and 1½ tons per acre for the Harney Valley.

EVAPORATION AND TRANSPIRATION TEST.
NEAR BURNS, ORE.
Location: Wickes Field. Mean of two pans.
Soil: 4 in. peat, 32 in. sediment.
Growth: Sugar grass and mixed meadow grasses.
Evaporation = 12.10 in.
Transpiration = 5.60 in.
Weight of cutting, green, 26.4 oz.
cured, 7.9 oz.
dry, 4.7 oz.
Transpiration ratio to green weight, 128
do hay " 409
do dry matter, 682

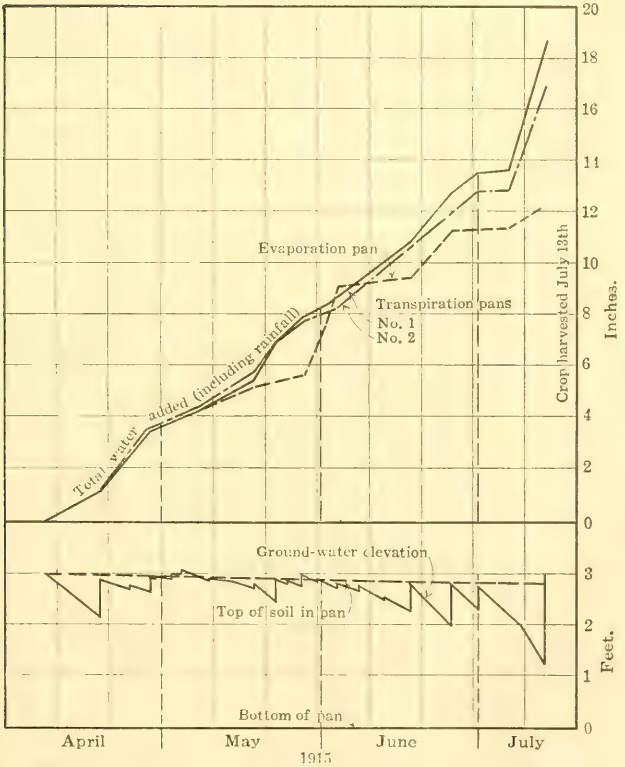


FIG. 15.

Soil Absorption.—When a quantity of water is applied to the surface of a dry soil, it sinks and is absorbed by the soil, traveling downward and laterally until the distribution is such that all is held by capillarity. When a balance is obtained, the water again begins to travel upward to replace the moisture evaporated from the surface, and so continues until a condition is reached when the quantity of moisture is so slight that no travel will occur. Although the total voids may be equal, in two soils having particles the effective diameter of which is widely different, the storage capacity of the soil of finer texture is the greater, and likewise its resistance to percolation, due to the greater surface tension of the smaller particles. Different plants require different proportions of soil moisture in order to produce the best results. When the percentage of soil moisture drops below certain limits, the roots refuse to take up more, and the plant wilts. Table 11 gives the percentage of moisture below which the plant growth comes to a standstill and the plant wilts.

As the percentage of moisture required for plant growth exceeds the quantity which will be held by capillary action, it is clear that in permeable soils a balance cannot be reached, as previously stated, but there must be a continuous movement of water downward in irrigation. This is called percolation. If, however, the soil is underlain by an impermeable stratum which prevents a continuous downward motion, the soil moisture may be held above the wilting point without percolation losses.

EVAPORATION AND TRANSPIRATION TEST.
NEAR BURNS, ORE.
Location: Frye Field. Mean of two pans.
Soil: Silt loam
Growth: mixed meadow grasses.
Evaporation = 8.90 in.
Transpiration = 4.10 in.
Weight of cutting, green, 15.12 oz.
cured, 4.53 oz.
dry, 2.72 oz.
Transpiration ratio to green weight, 73
do hay " 242
do dry matter, 403

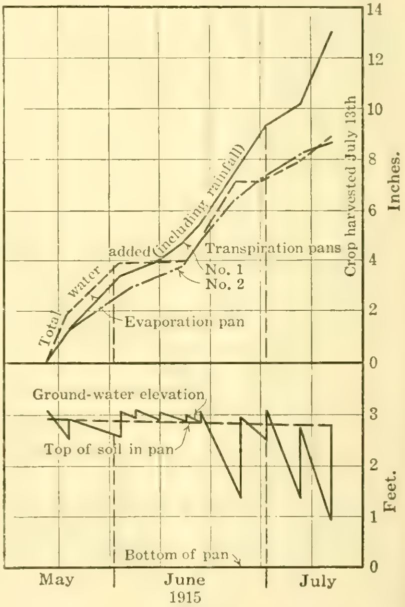


FIG. 16.

The foregoing description is given in order to show that soil absorption and percolation act in most conditions and for most crops; it is not given as a statement of the case for the experiments described in the following.

The soil of the Chewaucan Marsh consists of a layer of true peat, from 1 to 4 ft. thick, underlain by a few feet of mixed soil, under which occurs a bed of chalky soil of great depth. The chalky soil is continually saturated, and the ground-water during the non-irrigation season is within a few feet of the surface. During this season, as seen by Tables 5 and 6, an average of more than 8 in. of rain occurs, which offsets evaporation to such an extent as to prevent any great lowering of the ground-water level. As soon as irrigation is discontinued, the peat soil dries very quickly, but the lower stratum of the peat being very compact and the texture of the subsoil being very close, there is not a great deal of water drawn from the subsoil. Post holes dug during October showed a low percentage of moisture at a depth of 3 ft.

EVAPORATION AND TRANSPIRATION TEST.
NEAR BURNS, ORE.
Location: Verdo Field. Mean of two pans.
Soil: 10 in. peat, 26 in. sediment.
Growth: Sugar grass
Evaporation = 7.50 in.
Transpiration = 8.60 in.
Weight of cutting, green, 30.2 oz.
cured, 9.1 oz.
dry, 5.4 oz.
Transpiration ratio to green weight, 164
do hay " 597
do dry matter, 912

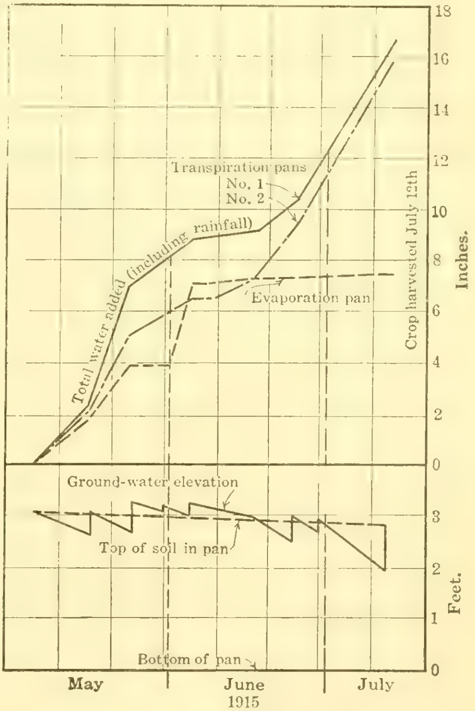


FIG. 17.

The character of the crops on Chewaucan Marsh is such as to require continuous flooding to a depth of several inches above the surface during the irrigation season and the continuous movement of the water during that time. An examination of the nature of the growth on different parts of the marsh, with an analysis of the topographical conditions, shows that any departure from this condition of continuous flooding has an immediate effect on the character of the growth. Wherever the flow of water is checked,

EVAPORATION AND TRANSPIRATION TEST.
NEAR BURNS, ORE.

Pan No. 2, Wickes Field.
Soil: 4 in, peat, 32 in. sediment.
Growth: Sugar grass and mixed meadow grasses.
Evaporation = 15.78 in.
Transpiration = 8.70 in.
Weight of cutting, green, 41 oz.
cured, 12.5 oz.
dry, 7.5 oz.
Transpiration ratio to green weight, 122
do hay " 402
do dry matter, 669

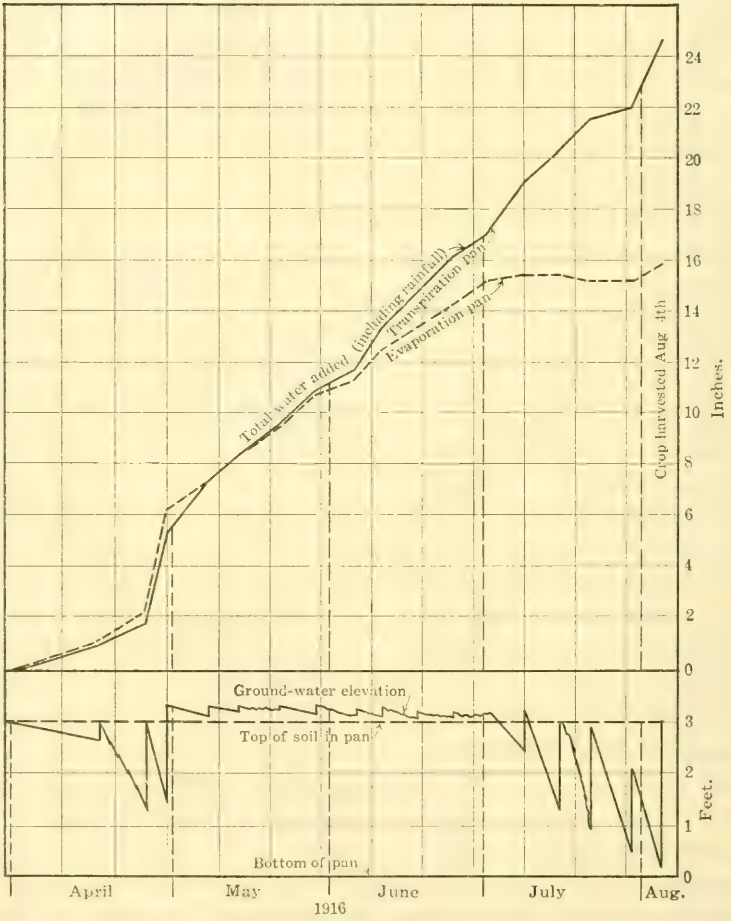


FIG. 18.

so that it is practically at a standstill, the beneficial growth is changed to tules, cat-tails, and other plants having no crop value. Wherever knolls occur, so that the water does not cover the surface, the growth changes to fox-tail, bluejoint, and other grasses of less value than those covering the larger part of the marsh.

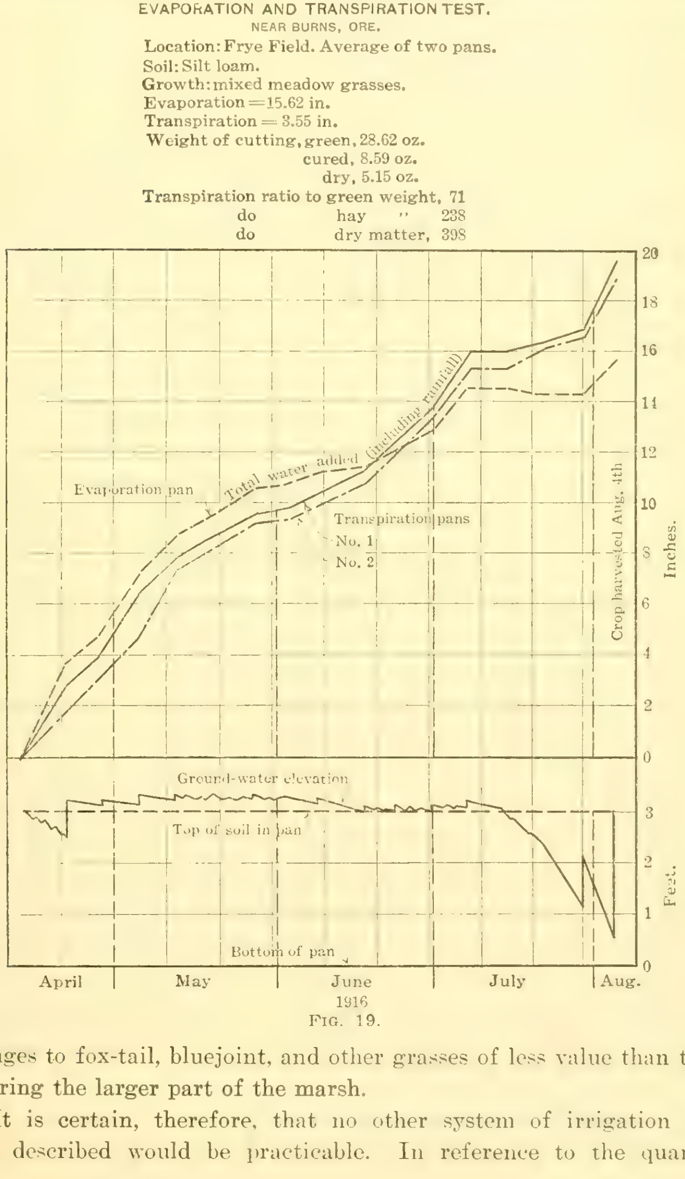
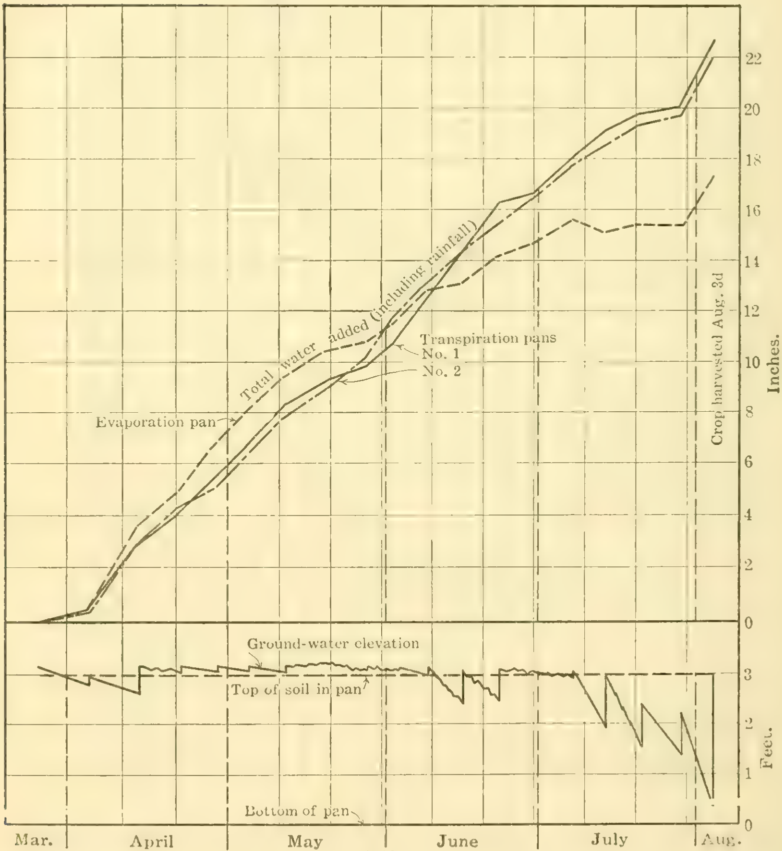


FIG. 19.

It is certain, therefore, that no other system of irrigation than that described would be practicable. In reference to the quantity



EVAPORATION AND TRANSPIRATION TEST.
NEAR BURNS, ORE.

Location: Verdo Field. Average of two pans.
Soil: 10 in, peat, 26 in. sediment.
Growth: Sugar grass.
Evaporation = 17.33 in.
Transpiration = 4.95 in.
Weight of cutting, green, 27.5 oz.
cured, 8.25 oz.
dry, 4.95 oz.
Transpiration ratio to green weight, 104
do hay " , 346
do dry matter, 577

FIG. 20.

TABLE 11.—RELATION BETWEEN HYGROSCOPIC MOISTURE CONTENT AND MOISTURE CONTENT AT WHICH PLANTS BEGIN TO WILT.

Bulletin 50, U. S. Bureau of Soils.

Soil.	Water content at saturation. Percentage.	Hygroscopic water content. Percentage.	Water content at which plants begin to wilt. Percentage.
Coarse sand	26.5	0.42	1.5
Medium fertile garden soil	43.9	1.68	4.6
Infertile sandy muck	41.4	0.97	6.2
Sandy loam	43.3	2.40	7.8
Very fertile calcareous soil	38.3	3.65	9.8
Peat soil	274.0	20.6	49.7

Percentages given by weight, and not by volume.

of water absorbed by the soil, therefore, one must consider, not only a thoroughly saturated soil, but a water cover of sufficient depth to insure a surface velocity sufficient to supply the needs of the beneficial grasses.

To determine the quantity of water which would be absorbed by the soil at the beginning of the irrigation season, the following experiments were performed, and the following calculations made:

First.—The porosity of the soil was determined, roughly, by making an excavation to a depth of 4 ft., and accurately measuring its size. A water-tight box was then constructed having the same cubical capacity as the excavation. After drying the earth taken from the excavation, it was replaced in the box in such a manner as to occupy the same space as it did in place. Water was then measured into the box until the soil was thoroughly saturated, and thus the percentage of voids was determined, and found to be 58 per cent.

Second.—From the writer's previous work in soils of a similar nature, it was found that, with ground-water at a depth of about 8 ft., soil evaporation would be negligible, and, for any depth to ground-water of less than 8 ft., the quantity of evaporation would be proportional to the depth. A similar conclusion was reached by Mr. Lee, in his work previously cited.* With this as a basis, and using the mean monthly temperatures and mean monthly precipitation for the non-irrigation season, namely, from July 1st to March 15th, Table 12, showing the depths to ground-water at different periods, was computed. In doing this, it was assumed that irrigation would be stopped on July 1st and that the marsh would be uncovered progressively from July 1st to 31st, inclusive—evaporation thus taking place over half the marsh during July.

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* *Water Supply Paper No. 294*, U. S. Geological Survey.

TABLE 12.—PROGRESSIVE DRYING OF SOIL DURING NON-IRRIGATION SEASON FOR CHEWAUCAN MARSH.

Month.	Evaporation from water surface. in inches.	Percentage.	Sub-surface evaporation, in inches.	Rainfall, in inches.	Depth to ground-water, in inches.
July	4	97	3.88	0.80	5.50
August	7	90	6.30	0.37	15.35
September	5	82	4.10	0.76	20.85
October	3	77	2.31	0.82	23.33
November	1	76	0.76	1.32	22.63
December	1	76	0.76	0.96	22.38
January	1	77	0.77	1.51	21.26
February	1	78	0.78	1.21	21.03
March 1st to 15th	1	78	0.78	0.52	20.66
	24	....	20.44	8.27	....

From Table 12 it is seen that ground-water would reach its lowest depth on October 31st, and that, on March 15th, it would be at a depth of 20.66 in. below ground surface. It is not meant by this that the actual ground-water would be at this depth, but that the condition of the ground for the first 8 ft. would be as though ground-water was at this elevation and the soil was dry above it. The quantity of subsoil evaporation to be replaced at the end of this period is seen from Table 12 to be 20.44 in., less a rainfall of 8.27 in., during the same period, or a net depth of 12.17 in.

As a check on this computation, and also in order to determine the rate of absorption, a special apparatus was devised for making a more accurate test in place. This apparatus (Figs. 14, 21, and 22) consisted of a heavy sheet-iron tube, 5 ft. long and 10 in. in diameter, to the top of which was riveted a heavy band for driving. The bottom of the tube was sharpened to a fluted knife-edge for the purpose of cutting through the sod into the subsoil before beginning to drive. This tube was set up vertically over the place to be tested, and turned with a long lever until it had cut through the sod to a depth of about 12 in. It was then driven with wooden mauls through the soil and into the chalky layer below so as to enclose an area of the original

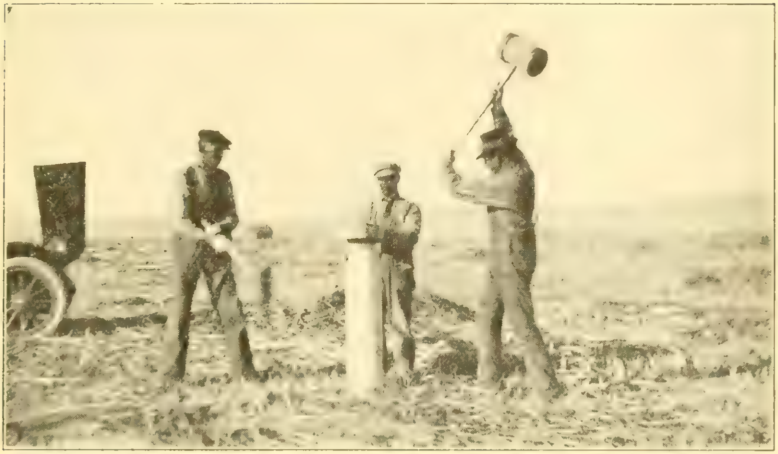

Fig. 21.—Sinking Tube in Subsoil by Driving.

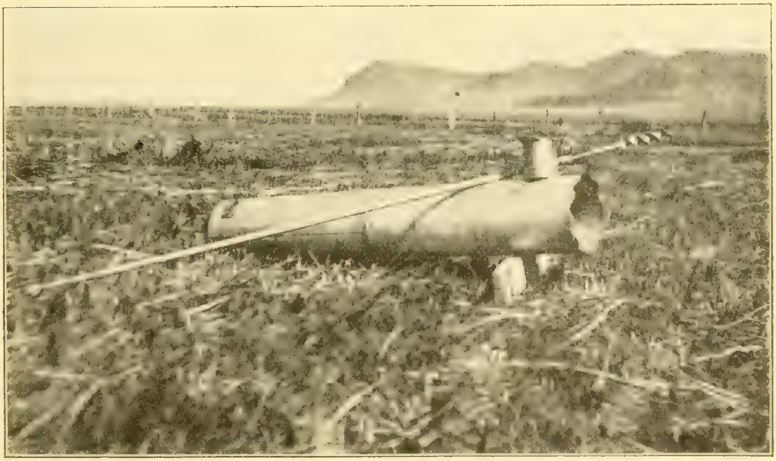

Fig. 22.—Apparatus Used in Soil Absorption Test.

soil 10 in. in diameter in the water-tight tube. Borings, adjacent to the tube, were made with a soil auger in order that the nature and depth of the soil could be recorded. Water was then measured into the tube with a quart measure, and replenished at stated intervals, the depth of water added being recorded at the time. The top of the tube was kept covered in such a manner that no evaporation could take place. The result of this test is shown on Fig. 23.

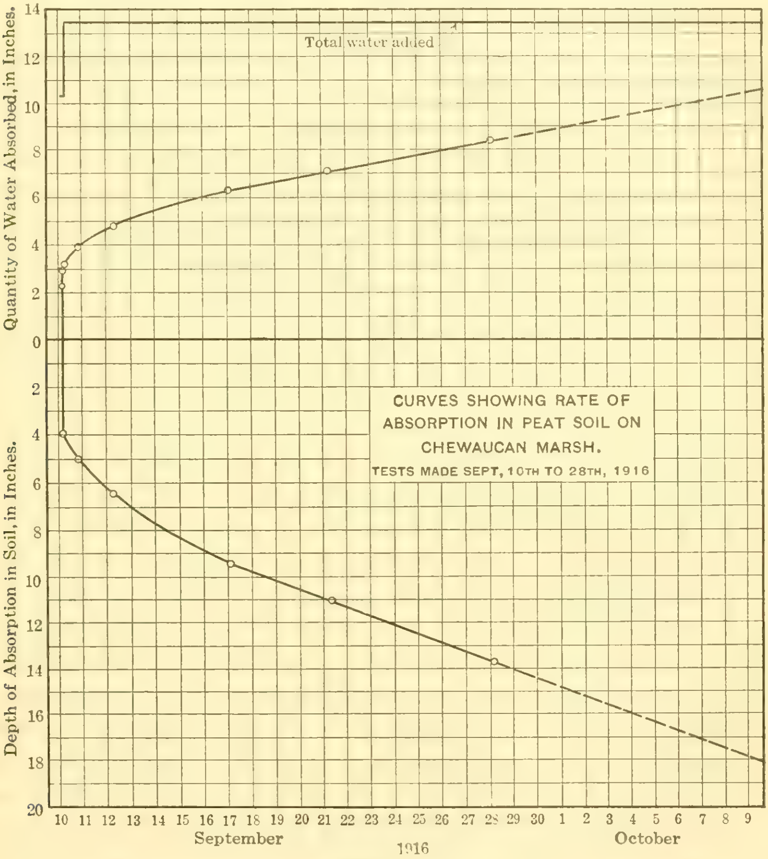

FIG. 23.

It will be noted from the curves on Fig. 19 that the water sinks almost immediately to a depth of 4 in., the rate of absorption then gradually diminishing until a depth of about 10 in. is reached, when the rate of absorption becomes fairly uniform. It will also be noted that the soil requires about 6 weeks to reach a saturated condition.

It is probable that the actual rate of absorption on the marsh is somewhat greater than that shown in the test. During dry weather, the surface of the marsh cracks to some extent, the cracks extending some distance into the soil. These cracks lead the water to a good depth immediately, and allow it to distribute laterally as well as vertically. In the test, however, no crack was included within the limits of the cylinder sunk into the soil, and, therefore, this lateral distribution would be eliminated.

In Harney Valley, the soil in general is of a different nature. The writer found, by borings made in October, 1916, about 2 months after harvest time, that the soil was quite dry for a depth of 2 or 3 ft., gradually increasing in moisture below that depth until a saturated condition was reached at a depth of about 5 ft. Soil samples were taken at various locations, and a porosity of from 27 to 52% was found. The subsoil is such that considerable percolation occurs, both vertically and laterally, the latter being very noticeable in the growth of grasses and the deposit of alkali on areas not irrigated. It was found that lateral percolation would be apparent at a distance of 500 ft. from the nearest place where water was applied on the surface.

As the rainfall from October to March is generally sufficient to offset soil evaporation, and as the soil in test holes was found to be dry for a depth of 3 ft., the quantity of moisture which would be absorbed in the 3 ft. would vary, according to the texture of the soil, from 10 to 18 in., or an average of about 14 in.

Percolation and Run-Off.—One of the principal losses of water in irrigation, and likewise the hardest component to determine, is that of percolation and run-off. As heretofore stated, it is impracticable to supply to the soil the exact quantity of moisture needed for plant use and evaporation and still keep it in the right condition of moisture to obtain the best growth. The best yields per acre are obtained in soils which have a natural drainage, that is, where the soil itself is underlain by a more open subsoil, permitting the excess waters to percolate freely and be carried to some watercourse. Where underground drainage is not obtained in this manner, it sometimes happens that the excess water applied in irrigation accumulates in the soil and gradually raises the water-table until harm is done to the plant life. In these cases, it becomes necessary to put in an artificial system of drainage, consisting either of open-drain ditches or buried tile drains leading to some watercourse where the excess water may be discharged.

In the case of the growths considered in this paper, however, no harm is done by lack of under-drainage; on the contrary, the plants thrive in a saturated soil, and, in the case of sugar grass, even require moving water on the surface of the ground. It is a decided benefit, therefore, to have an impermeable subsoil and a lack of under-drainage, as this eliminates losses by percolation which would otherwise occur.

On the Chewaucan Marsh, as heretofore stated, the subsoil is of an impermeable nature, and there is practically no loss from percolation, but, as the sugar grass requires a saturated soil and free water moving over its surface, and as the configuration of the marsh is such that an absolute uniform depth cannot be obtained, the depth must be such as to cover the high points. The least mean depth which will cover the marsh and submerge it as a whole was found to be from 4 to 6 in., at which the depth would be practically zero at the high points.

The least velocity at which the surface water needs to move, in order to prevent it from becoming stagnant and changing the character of the growth, has never been determined. A determination was made of the velocity under present conditions, both by calculation from physical conditions and by observation of the current as it exists, and this velocity was used to compute the quantity necessary for run-off. It is possible that works might be established by which this velocity could be made less without harm to the plants, but this is not known, and it is very doubtful if the velocity could be diminished much without producing damaging conditions.

Using the velocity thus obtained and the cross-section of the water cover at various points on the marsh, the writer calculated that the loss of water by surface run-off was about 23 in. in depth over the acreage irrigated.

As before stated, the nature of the soil, the growth, and the topography of the country in the Harney Valley are much different from that on the Chewaucan Marsh. The surface soil in Harney Valley consists of a medium silt loam on the surface, with occasional areas of peat soil, the whole being underlain with a sedimentary silt having particles with an effective diameter of about 0.5 mm. The valley is cut up considerably by watercourses, dams in the latter serving to deliver the water to the land, the excess being dispersed by run-off, by longitudinal percolation to Malheur Lake, and by lateral percolation to the streams below the dams, and in these it continues to the lake.

Excepting for the sugar-grass areas, continuous surface flooding would not be necessary, from the standpoint of growth; but, considering the fact that both soil and water are quite alkaline, such flooding is necessary to keep this alkalinity from becoming detrimental to growth. Outside of sugar grass, the growths found in the valley thrive about equally under continuous flooding and intermittent flooding sufficient to keep the soil saturated. However, as the latter is strongly impregnated with alkaline salts, any condition which will cause the soil water to be brought to the surface and evaporated, will cause a deposit of the salts, which is destructive to vegetation. By continuous flooding, the salts are prevented from being deposited, and the growth continues until the final shutting off of the water, when they are deposited up to the time when the soil is dry, but too late to damage the growth to any extent. The salts deposited after the irrigation season are washed off with the first rush of water in the spring, and this allows the new growth to start.

The loss by longitudinal percolation is slight. As the effective diameter of the soil particles is about 0.5 mm., and the surface slope toward the lake is about 0.08%, the rate of percolation, longitudinally, would be only about 9 in. per day; but, as the valley is traversed by deep watercourses to which the water may percolate and be carried off directly, there are slopes as great as 4 or 5%, which would cause velocities of percolating water as great as 50 ft. per day. Even at this rate, however, percolation is small, as compared with surface run-off, and as there is great likelihood of error in calculating either one, it was considered in this investigation as included in the run-off.

Conditions of run-off were much the same as on Chewaucan Marsh, except that the water was not collected into a single channel on its discharge from the irrigated area, as in the case of the Chewaucan Marsh, and, therefore, no check could be made on the calculations as to the quantity of run-off. The country was also much more irregular than the surface of the marsh, and thus many knolls were left without surface cover, and, on the areas affected, the depth had to be greater than in the case of the marsh, in order to cover as much ground as possible. For this reason, the surface velocity of the irrigating streams was greater than on the Chewaucan Marsh, although the surface slope was somewhat less. It is safe to provide a run-off of at least 40% of the total delivery in order to protect against alkali. This would give about 24 in. of depth over the irrigated area.

Conclusion.—Though the investigation herein described was made necessary by the system of irrigation and a class of growth about which little was known, the same method of analysis may be used on any class of irrigation and any growth. By a study of the plant and its needs in regard to soil moisture, the method of application of the water may be determined; and by a study of soil and climatic conditions, an analysis of the use of this water may be made, which will vary in accuracy according to the extent of the investigation. It is not claimed by the writer that this method is always superior to that of direct trial, nevertheless, it is useful in some cases where that is impracticable, and in other cases it will give results which, taken in conjunction with the duty obtained by direct trial, will aid in the elimination of losses, the improvement in yield, and the betterment of irrigation methods.

In conclusion, the author wishes to acknowledge the assistance of Carl J. Rhodin, M. Am. Soc. C. E., to whom is largely due the work of comparison of evaporation data; and of Professor P. B. Kennedy, of the University of California, whose classification of the different plant growths encountered and study of the reasons for their occurrence were of invaluable assistance.

The writer has purposely omitted many of the factors which aided him in arriving at his conclusions, and even much of the detail in regard to the conclusions themselves, as the investigations described herein were for use in certain litigation which has not yet been brought entirely to a close. The purpose of this paper, therefore, is merely to show the methods used, and any figures given will be considered as merely exemplifying such methods and not as final determinations of results.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications.

ADDRESS AT THE ANNUAL MEETING, JANUARY 16TH, 1918.

By George H. Pegram, President, Am. Soc. C. E.

The abandonment of the Annual Convention last June on account of the War, moved the Board of Direction to request your President to deliver his Annual Address at this meeting.

Realizing the demands upon your time for other matters, I have viewed the action of the Board as largely a matter of courtesy, which I deeply appreciate, and shall endeavor to be brief.

The great world-war is imposing supreme tests of the virtues, faults, and philosophies of all peoples, and their industrial, economic, financial, and political organizations will undergo great changes.

In this reformation there is the greatest hope for the engineer; and as he has always been the keystone in the arch of war, he may become the keystone in the arch of peace.

Practically all the world's great military commanders have been engineers: Cæsar, Bonaparte, Wellington, in the past, and, in the present war, Joffre, Haig, and Hindenburg.

In our own country, many of the men who gained prominence during the Revolutionary War were surveyors, that being the general work of the engineer of that day.

Ira Allen, of Vermont, one of the ablest diplomats and financiers of his time, was a surveyor, serving for a number of years as Surveyor-General of the State. He was one of the first to propose building the canal to connect Lake Champlain with the St. Lawrence River.

General Stark, the hero of the Battle of Bennington, was a millwright. General Wayne, like his great commander, General Washington, was a surveyor, and, at the beginning of the Revolution, was surveying in Ohio. In our Civil War, the engineer was similarly prominent, and this was emphasized among the officers drawn from civil life.

War involves many engineering operations; in fact, at the present time, it has become an engineering science; so that we might expect such distinction, were it not that higher qualities than mere professional technique are required in generalship, which demands the organization and control of masses of men, and administrative ability of the very highest order. The engineer has so generally responded to these higher requirements in times of war, when the best services must be had, that we may reasonably ask why greater use is not made of his administrative qualities in times of peace.

Nearly three years ago, our engineers began the agitation of preparedness for war. In March, 1915, a committee was appointed whose work resulted in the law authorizing the Engineer Officers Reserve Corps, by which civilian engineers are made part of the army; groups of engineers in different parts of the country provided military lectures, preparedness parades, and other movements anticipating the possibility of our being drawn into the war.

The Administration at Washington, in appreciation of the services which might be rendered by engineers, wisely called them into council, resulting in the formation of the Naval Advisory Board, the Council of National Defence, and the Bureau of Scientific Research, in all of which our most skilled and prominent engineers have been from the first, and are now, unselfishly devoting their services to the needs of the country, without remunerative return, even for their expenditures; and our Society, as you know, offered its services to the President immediately upon the declaration of war, and has responded to every call.

An engineer, Mr. Herbert C. Hoover, has been selected for possibly the greatest administrative post, the head of the United States Food Administration, and to this Administration we have given the free use of our former home which cost a half million dollars.

In spite of the fact that but 11.5% of our membership is within the draft age limit, 11.0% is now in the army, and the number is rapidly increasing. Men of mature age, without previous military training, and whose prominence in the Profession would entitle them to entire immunity, have gone to the front. The names of Parsons, Wilgus, Bensel, Buck, and Hodge, among my intimates in New York, come to mind, and of course there are hosts of others.

The glorious record of the first appearance of the American soldier on the firing line of Europe fills us with pride. Our engineers were aiding Byng's advance on Cambrai with the construction of the military railroad, and progressed so fast that a recession of the line brought them on the front, when they dropped their picks and shovels and grasped guns from the wounded and dead and joined the fighting forces.

The Engineering Mission from the United States to Russia, consisting of John F. Stevens, John E. Greiner, W. S. Darling, George Gibbs, and Henry Miller, has performed a task which, despite the political revolution there, must bear great future fruit, for Russia, next to China, has the greatest undeveloped resources of any country in the world, and hereafter the field of the engineer, like the present field of the soldier, will be less limited by national boundaries.

Engineering is sometimes claimed to be a modern profession because the present appellation is of comparatively recent adoption. The practice, however, is of such ancient origin that, in considering its relations to the community, we are obliged to view its history. Most of our tools—the dowel, drill, chisel, wedge, screw, pulley, file, and saw—were used by the ancients.

No works of modern times compare in magnitude with those of the ancients. Consider a reservoir, to impound the waters of the Nile, covering an area of 150 sq. miles, with a dam 30 ft. high and 13 miles long. The pyramids of Gizeh, constructed more than 5 000 years ago, had granite blocks which were 5 ft. square and 30 ft. long, and were transported 500 miles. One of the temples of Memphis was built of stones which were 13 ft. square and 65 ft. long, and laid with close joints. The Appian Way from Rome to Capua was so well built that after a thousand years its roadway was in perfect condition, and, even now, after two thousand years, with slight repairs, is in use. The modern engineer would question the possibility of such work, without these great examples.

If one could imagine cessation of life on this continent, and our works subjected to the destructive forces of time and Nature for a thousand years, what evidences of civilization would remain?

Probably the most surprising and interesting of the older examples of engineering are the inventions of Leonardo da Vinci, as shown in his sketches. He seems to have lacked nothing but the application of mechanical power to produce most of the typical machines of the present day. The bellows-blast, jig-saw, lathe, rolling mill, printing press, file-cutting machine, trip-hammer, sprocket-chain, water-wheel, boring machine, rapid-fire gun, spinning machine, side-wheel boat, flying machine, etc., and I commend to your notice the work of Franz M. Feldhaus on "Leonardo da Vinci as Engineer and Inventor", published in 1913. In this work is shown an apparatus of cylinder, piston, and valve by which Leonardo determined the relative volumes of steam and water; also an atmospheric engine, consisting of cylinder, piston, and valve, by which reciprocal motion was produced.

The pity is that, in all his machinery requiring mechanical power, and in spite of his experiments hinting at its application, he still was limited to muscular effort, and it was not until the invention of Watt that the mystic wand of mechanical power initiated a transformation of the world and made a radical change in the organization of man.

We look in vain for the application of mechanical power by the ancients, whose works seem almost impossible without its assumption, but the stone reliefs showing the movement of large weights by manual power indicate that probably the other did not exist.

An entirely new economic system has been developed in this age of mechanical power, and in that sense the engineering of the present day is modern, and the relations of the engineer to the community are more important and intimate; but such is the force of precedent that these relations have undergone very little change in all past history.

There is now rapidly developing a wave of collectivism, so to speak, or class power, engendered by the ease of over-production and the education of the masses. It will render the community work of the engineer more easy and also more necessary, for, if individualism is not protected, we must drift toward the jungle.

In our democratic aim to give equality of opportunity, we are losing sight of the fact that progress and civilization itself rest upon the achievements of individuals, and this is being demonstrated clearly in the present war, as it is in every crisis.

Invention and initiative require special opportunities and encouragement, and efficiency demands that those who are to direct shall be selected through the exercise of wisdom, and it must be admitted that the policies, practices, and tendencies of the present time are not adapted to achieve this result.

The operation of competition to select the most fit is being more and more restricted, both by law and through combinations of men, and no process is proposed by which the survival of the fittest may be assured.

Admitting that the efforts of any individual are directed to securing existence, comfort, and power for himself, he is best benefited by a system which shall produce for the community the greatest total wealth.

The engineer, by his education and technical training, and especially by the confidence of all classes of the community which he enjoys, is well prepared to enter actively into public discussions and public service, and should do so.

To that end the engineer should form local associations, devoted, beyond the consideration of the technical and scientific aspects of engineering, to the larger service to the community as a co-operative part in public affairs.

One great lesson of the war is that the community should always have men of experience qualifying them to act as leaders in the various lines of activity when the emergency of war arises, and masses of men whose training would permit of their being quickly formed into an army.

It would seem as if this might be accomplished without the necessity of a large standing army and compulsory military training, which would not only involve a loss of energy, but would be a constant menace to peace.

When we consider that the cost of our greatest public work, the Panama Canal, represents but ten days' current cost of the war to England, it is evident that the construction of public works containing an element of military preparedness is justified, especially such works as will have an economic value commensurate with their cost independent of the war element.

The class of men liable to military service might be given periodic labor experience sufficient to keep them in physical condition for the emergencies of war, without much sacrifice of their normal occupations.

Engineers could well afford to supplement their technical training with a period of labor, especially in skilled lines.

Such public works would form a reservoir of employment for surplus labor in times of industrial depression. They would include the development of water powers, the construction of impounding reservoirs for irrigation and navigation purposes, canals and improvements of rivers, the reclamation of waste lands, and the needed enlargement of our railways, terminals, highways, etc.

In spite of days of work and nights of study which is the lot of the engineer, time must still be devoted to broader interests, and there is great need of such service.

With the greatest heritage of natural wealth in all the world, we are most prodigal and wasteful in its use. We have the largest supply of coal of any country, and, knowing that civilization itself, in a modern sense, depends upon the coal supply, we are told that in the short space of 200 years, if its consumption increases at the present rate, our coal will be exhausted. What a brief period compared with the 5 000 years of recorded history of China, which, with a coal supply next in size to our own, imports coal. The conservation of this mineral devolves upon the engineer, not only in the improvement of machinery with which its power is applied, but in the utilization of water power, the improvement of natural waterways, and the construction of canals, by which transportation costs can be lessened.

Eighty years ago, or within the lives of many now living, the canals of the United States, more than 2 500 miles, exceeded the railways in length. It was then possible to make the trip by water, completely around the eastern part of the country, from New York to Buffalo, by river and canal, thence to Cleveland by lake, to the Ohio River by canal, and thence by river to the Gulf.

An English engineer, writing of New Orleans at that time, said: "At every hour, I might almost say, every minute of the day, magnificent steamboats which convey passengers into the heart of the western country, fire off their signal guns and dash away at a rate that makes me giddy to think of."

At that time there were boats on the Mississippi River with a capacity of more than 1 000 tons, which exceeds the capacity of any of the present boats; and, subsequently, boats with a capacity of more than 3 000 tons were operated.

Previous improvements of our rivers have been piecemealed, we have aimed at quick results instead of conforming to a comprehensive scheme. Navigation has faded away in regions where millions have been spent to preserve it. Flood lands which, by proper regulation of the river and by the deposition of sediment, might have been built up, have been protected by expensive levees which have prevented the natural process of reclamation. Floods which should be impounded for service in dry times are allowed to run to waste.

We are taught that the mouth of the Mississippi was once at Cairo, more than 1 000 miles from the Gulf, by the river, and that the great fertile valley was formed by alluvial deposits. These alluvial deposits are not only needed to raise the surface of the land, but are very rich in fertility. We have leveed the river so that the sediment is deposited in the Gulf, where it is not only lost to land building but entails constant labor in jetty building and dredging to keep the mouth of the river open to navigation. The levees are being built higher and higher at great cost, and the lands they are designed to protect are being eroded and their fertility exhausted. This would seem to be a problem where the engineer might "direct" the forces of Nature for the "use and convenience of Man" instead of opposing them.

Man is the only animal that invents. He can thus change his environment, which in turn re-acts to change him. We rise from purely animal conditions by the aid of invention. We can sink back by its loss. Little do they realize, who claim that labor produces all wealth, how paltry would be the results of labor without invention and design.

The Constitution aims to encourage invention. It is a common thing to find organized opposition to it, as for instance the proscription of the use of patented articles in city work, and the efforts of construction, industrial, and railway organizations to fight patents, and the professional opposition to their exploitation.

Of course, one with an established business is naturally placed in opposition to a monopoly which threatens successful competition or possibly ruin to that business. Further, the inventor is usually unable to perfect his inventions through want of means. It would seem that a way should be found whereby the community would profit in encouraging invention probably by granting less monopoly to the inventor, but on the other hand, rendering him more help. Invention is an individual matter. Committees cannot invent.

Although invention is quite apart from engineering, the work of the engineer is largely based on former inventions.

In the past year our Society joined with the other Founder Societies in the formation of the Engineering Council, designed to represent the present growing membership of more than 30 000 engineers in the consideration of public matters.

Though in itself the greatest step that has been taken looking to the advancement of the Profession, the movement is especially inspiring as indicating the determination of the engineers to co-operate. At the magnificent celebration at which we were welcomed to our new home by the other Founder Societies, this sentiment was expressed by all the speakers in entire accord.

With such unanimity of purpose, our prospects are indeed encouraging.

Other steps are necessary, however: The Council must act with conservatism commensurate with its dignity and responsibility. It would seem that an organization should be formed devoted to the material interests of the younger men, draftsmen, instrument men, inspectors, etc., with such association with the older engineers that their development and progress may be encouraged; in brief, an alliance of all engineering interests which would be in harmony with similar organizations in nearly all lines of endeavor.

To co-operate effectively with other classes of the community, we must be organized for concerted action in our own sphere.

The prompt and intelligent direction that could have been given to the engineering forces in preparation for the war, had such an organization existed, would have been of great advantage, not to speak of the benefits to the engineers themselves.

The lawyer whose work is in direct contact with the people, and whose public services as law-maker as well as expounder enables him to protect his interests, has the further advantage of public prominence which often leads to his selection on commissions of a technical nature, to the exclusion of the engineer.

The members of the medical profession long ago recognized the necessity of impressing the people with the value of their public services. Schools of contrary theories have co-operated for a common end. Laws governing sanitation and hygiene have resulted, and frequent accounts of their work appear in the press. They have unselfishly disclosed what were formerly regarded as professional secrets, and have gained the well-merited recognition of the public.

The Engineer should profit by example.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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OBSTRUCTION OF BRIDGE PIERS TO THE FLOW OF WATER

Discussion.*

By David A. Molitor, M. Am. Soc. C. E.

Mr. Molitor.

David A. Molitor,† M. Am. Soc. C. E. (by letter).‡—The writer had occasion to devote several months to this problem in making computations relative to the Kansas City Northwestern Bridge over the Kaw River at Kansas City, Mo. The case was brought by the Kansas Drainage Board against the Missouri Pacific Railway and many eminent members of the Profession gave testimony.

The case was extremely complicated, as the bridge in question was located at about 36° with the stream center line, with four piers normal to the bridge axis, and the river on a curve. There were fifteen other bridges up stream from the one in question, all of which influenced the flood stage and back-water conditions involved in the controversy. The last testimony was given in May, 1915, and the State Supreme Court recently decided the case in favor of the Railroad Company.

When Mr. Nagler's paper appeared, in May, 1917, the writer naturally gave it a careful reading and attempted to incorporate the experimental data into his former calculations, but without success.

Although the author gives a formula for back-water height produced by bridge piers, his experiments certainly did not warrant the broad conclusions which he draws, and it is questionable whether the main purpose of the experiments "to determine the relative obstruction to the flow of water offered by piers of different designs" was answered satisfactorily.

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* Discussion of the paper by Floyd A. Nagler, Jun. Am. Soc. C. E., continued from January, 1918, *Proceedings*.

† Detroit, Mich.

‡ Received by the Secretary, January 18th, 1918.

Mr. Molitor.

The most valuable contribution to science, of any experimental research, is always a publication of the complete observations, as these constitute the best evidence. An author's deductions may be wrong, but the experiments, if published, may enable the reader to locate the trouble. In the present case, only enough data were published so that the thread of the argument could be followed.

In so far as the author's experiments include only one span length of 2.138 ft. obstructed by a single pier 0.5 ft. wide, he has eliminated all the variables in the problem except depth of water and velocity, so that his empiric constant is not put to the severe test of satisfying all the conditions generally imposed. Therefore, the summary dismissal of all previous formulas wherein the coefficient varies as much as 9%, was entirely unwarranted in the face of his experiments.

The further conclusion that the older formulas "have been disregarded by modern investigators, as the losses at the tail of the pier and the standing wave have been entirely neglected", is also incorrect, when ordinary bridges are under consideration. The writer has observed many bridge piers in swift currents, but has never seen a case where these conditions extend over the span from pier to pier. The heading up above a pier and the standing wave are purely local conditions at a pier, but, in the author's flume, they became general conditions, owing to the small width of the flume and the comparatively large obstruction offered by the pier. This, then, explains why the experiments did not fit any hitherto known formula, and necessitated the introduction of two constants, α and β, to bring about the required agreement; at the same time they rendered the formula worthless for general application.

There also appears to be an error in the algebraic substitution of the value $D = H_2 - \alpha \frac{V_2^2}{2g}$ and $H = H_d + \beta \frac{V_1^2}{2g}$ into the general formula $Q = C\,W\,D\sqrt{2\,g\,H}$. The final equation should give the value of H_d, and not of H, as given on p. 839.*

At the bottom of p. 829*, H_d is defined as "the difference in elevation between the bottom of the flume at Gauges Nos. 1 and 2", and hence the final formula in reality gives the bottom drop instead of the heading up due to the pier.

Regarding the author's conclusions, the writer emphatically objects to the first one, on p. 843*, as nothing of the kind has been demonstrated in the paper.

The second conclusion is true if the second sentence is omitted, as the author's formula is in no wise comparable with existing formulas.

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* *Proceedings*, Am. Soc. C. E., May, 1917.

Mr. Molitor.

The third conclusion is correct, but the fourth is extremely doubtful, owing to the fact that the experimental conditions are not representative cases when applied to bridges in general.

The phenomena accompanying the flow under a bridge demonstrate clearly that the back-water is essentially produced by the contraction of the channel, necessitating an increased velocity through the contracted area in order that the quantity of discharge may remain constant at all sections above, below, and at the bridge. This is directly observable, without resorting to small experiments for proof, and is shown by numerous photographs collected by the writer. The local effect at a pier, though influencing the back-water, does not extend over the entire span, but acts in the manner of an end contraction, as for a submerged weir. Hence, the empiric coefficient must be dependent on the number of such end contractions, the depth and velocity of flow, and the contracted width of channel. Therefore, such a coefficient must be expected to vary between somewhat wide limits, if all these variable conditions are considered, without discrediting the fundamental hydraulic formula to which it is applied.

This should dispel any hope of ever devising a back-water formula applicable to all bridges, which would embrace a coefficient depending only on the shape of the piers.

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THE CAPE COD CANAL
Discussion.*

By William Barclay Parsons, M. Am. Soc. C. E.†

William Barclay Parsons,‡ M. Am. Soc. C. E. (by letter).§—The discussion by Clemens Herschel, Past-President, Am. Soc. C. E., adds much interesting matter to the paper, especially in bringing out his own constant and consistent efforts in advocating a sea-level canal and combating the unexamined fear of a destructive tidal current. The writer's reference to Gen. Foster's contribution is possibly too broad, because, as Mr. Herschel points out, there are certain laymen who, even to this day, are prejudiced against an unlocked canal, but, after Gen. Foster's report, no serious consideration was ever given to a lock by those seriously interested in the matter, as far as the writer has been able to ascertain. Mr. Parsons.

The writer is distinctly pleased with the clear and forceful manner in which Mr. Herschel brings out the folly of any attempt at guard-gates or any means of partial control of tidal currents. A canal must be either a lock or an open canal. Any contraction caused by a lock or guard-gates will produce local difficulties and such a local increase in current velocity as to defeat the idea of a compromise. In the Kaiser Wilhelm or "Kiel" Canal, not lock-gates but actual locks were constructed, on account of marsh drainage, as Mr. Herschel points out. It was expected that, on ordinary neap tides and during a part perhaps of all tides, the gates might remain open and the canal be a tidal waterway. It was at once found, however, that a local current developed, due to the contraction of the area of the cross-

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* Discussion of the paper by William Barclay Parsons, M. Am. Soc. C. E., continued from November, 1917, *Proceedings*.

† Author's closure.

‡ New York City.

§ Received by the Secretary, February 6th, 1918.

Mr. Parsons. section, and that this was inconvenient, although the tidal current in the whole canal was negligible. On this account the gates are always kept closed, and the canal is used at all times as a lock canal.

If page 1130* of the paper is read, it will be seen that Mr. Herschel, in his discussion, attributes to the writer a statement which he never made, namely, that times of high water at Stations 410 and 35 are, in the main, the result of the velocity of wave propagation in the canal. On that page it is stated that "the velocity of wave propagation" is "a function of the time interval between the high-water points of the two ends," and, further, that "high water along the canal at the consecutive stations will be reached in the time interval between the high waters at Buzzards Bay and Cape Cod Bay." The paper deals with a tidal wave passing through the canal, and, by "velocity of wave propagation" is understood the speed with which the crest of this wave travels. In canals where tidal action occurs at one end only this velocity is mainly a function of the depth of the canal. In the Cape Cod Canal, where there are considerable tides at each end, the velocity of wave propagation is dependent on the phase and amplitude differences of the actuating tides.

Messrs. Herschel and Thomson are right in advocating a wider and deeper canal. The present limitations were imposed by financial necessities. Although, in a larger canal, the tidal current would be increased, ease in navigation would also be increased. The effective current is that which acts on the vessel, and this rate is increased according as the cross-section of the vessel diminishes the area of the canal. It is obvious that, with the same vessel, if the canal cross-section is doubled, the vessel will take up only one-half as much, and, in round figures, the effective current will be reduced one-half. In constructing the enlarged canal, Mr. Thomson would find that suction-dredges are not adapted to handle the material found on Cape Cod.

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* *Proceedings*, Am. Soc. C. E., August, 1917.

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DETENTION RESERVOIRS WITH SPILLWAY OUTLETS AS AN AGENCY IN FLOOD CONTROL

Discussion.*

BY FRED. H. TIBBETTS, M. AM. SOC. C. E.

FRED. H. TIBBETTS,† M. AM. SOC. C. E. (by letter).‡—There are many important instances in which a considerable measure of flood control may be accomplished by detention reservoirs with fixed outlets, of a somewhat different character than those emphasized by the author. Both Gen. Chittenden and Mr. Morgan who has contributed a most interesting discussion citing a number of instances of possible flood control by detention reservoirs, could probably have mentioned other examples of the use which the writer has in mind. The following outline of the use of the Colusa Basin "rim land" as a detention reservoir will illustrate the principle involved: Mr. Tibbetts.

The Sacramento River, like most large and heavily silt-laden streams which have built up their own valley floor, now flows on a ridge flanked by overflow basins in which large bodies of land are from 5 to 25 ft. lower than the river banks. On both sides of the river the continuity of these flood basins is interrupted by ridges built up by tributary streams. In the northwest quarter of the Sacramento Valley lies Colusa Basin, one of the largest of these overflow basins, with an area of about 200 000 acres normally subject to overflow. About $5 000 000 has been spent in reclaiming this overflow land, and this

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* Discussion of the paper by the late H. M. Chittenden, M. Am. Soc. C. E., continued from January, 1918, *Proceedings*.

† San Francisco, Cal.

‡ Received by the Secretary, January 17th, 1918.

Mr. Tibbetts. work is now approaching completion. Four principal agencies are involved:

A.—Drainage canals and pumping plants, to care for surplus seepage and rain water;

B.—A continuous levee along the river frontage, to prevent overflow from river floods;

C.—A continuous back levee, to ward off, from the low lying lands, drainage naturally reaching these lands from hills, plains, and tributary streams to the westward; and

D.—A large artificial channel through the Knights Landing Ridge, which separates Colusa Basin from the next lower flood basin.

The back levee has been located so that it will exclude flood waters from the lower lands in the basin, but, during heavy storms, will allow temporary flooding of a considerable area of high land outside of the levee system. This area of excluded land, locally known as "rim land", thus acts as a detention reservoir, very greatly reducing the quantity of water which must be handled by the artificial outlet channel through the Knights Landing Ridge. The excluded land is so high that under normal conditions it drains off in a few days. It is used for farming purposes, a considerable portion having been devoted last year to the culture of irrigated rice.

The discharge through the outlet of this "rim land" or detention reservoir is fixed by the cross-section of the Knights Landing Cut itself, and the action, apparently, is closely analogous to that which will take place in the detention reservoirs of the Miami Conservancy District. The total area of water-shed tributary to the Knights Landing Cut is about 1 600 sq. miles, about one-half of which is comparatively level plain contributing but little run-off. The remainder consists of comparatively bare hills and mountains reaching a maximum elevation of about 2 000 ft.

Prior to reaching the "rim land", the run-off from about 80% of the tributary area spreads out over "Upper Colusa Basin", which in the main is unleveed, and which in itself acts naturally as a temporary detention reservoir.

The average estimated annual run-off is about 230 000 acre-ft., the maximum being 705 000 acre-ft. The back levee corresponds to the dams of the detention reservoirs of the Miami Conservancy District, and is comparable in size, the main levee line being about 25 miles in length, with a maximum height of about 26 ft., and containing in all about 11 000 000 cu. yd.

The total storage capacity of the "rim land" at the elevation of the crest of the back levee is 464 000 acre-ft., or about twice the average annual run-off.

Mr. Tibbetts.

At the projected freeboard on the levees of 8 ft., the rim land will have a storage capacity of about 170 000 acre-ft., equal to about three-fourths of the average annual run-off, and about one-fourth of the maximum annual run-off. A careful analysis of flood conditions as they would have been if controlled by the present project in the 1911 flood, which is the greatest recorded on these water-sheds in the 30 years that records have been kept, shows that the rim land detention would have reduced the discharge which the Knights Landing Cut must handle from 26 000 to 17 300 sec-ft., or 8 700 sec-ft., or approximately one-half of the remaining required capacity. Actual measurements of the smaller floods of 1916, after the Knights Landing Cut had been put into operation, showed that the maximum discharge in the Knights Landing Cut was only 47% of the maximum discharge into the detention reservoir of the rim land.

The location of the back levee line in such a way as to exclude a portion of the overflow basin has permitted a great reduction in the size and cost of the artificial outlet channel, without preventing the use of the excluded land, although, of course, it impairs its value, because it prevents it from being settled, although not from being farmed. There are a number of other locations in the Sacramento Valley and elsewhere in California, where similar results can be obtained from the utilization of the high portions of the flood basins as detention reservoirs, and the writer does not doubt that there are other important instances where similar treatment is possible.

Comparative Costs.—The Miami Conservancy District is apparently placing its chief reliance for flood control on detention reservoirs, but its plans also include extensive channel improvement and levee work. The comparative costs of a given measure of flood control, where the two methods are available, is unfavorable to channel improvement and levee construction, because of the general lack of adequate equipment for work of this class in the Mississippi Valley, as compared with that in use in California.

On a recent cursory inspection of the proposed channel improvement at Dayton, the writer was somewhat surprised to be told that local contractors believed that gravel could not be handled successfully with a suction dredge "because 200 000 or 300 000 cu. yd. would wear out the pipes". The Sacramento River West Side Levee District is using a 20-in. suction dredge for levee construction, and, with this dredge, has already placed 1 830 000 cu. yd. of sand and gravel, at an average cost of 10.7 cents per cu. yd. This cost is abnormally high, because much of the work was done in short and scattered sections. In one continuous section of about 5 miles of levee, 1 062 000 cu. yd. were placed, at an average cost of 8½ cents per cu. yd., these figures including all overhead expenses, as well as operation, interest, depreciation, and maintenance. The material varies greatly, much of it

Mr. Tibbetts. being gravel suitable for concrete. A mechanical analysis of one section from which material is being borrowed for heavy concrete structures, shows that from 62 to 70% is gravel from ¼ in. to 1¾ in. in size. It seems to the writer that most of this material is harder and sharper than that in the river at Dayton. No new pipe has been bought since the work began, two years ago, and none has worn out. There does not seem to be any good reason for gravel wearing the pipes more rapidly than sand, except perhaps at bends. Sand is considered a better material for levee construction than clay, because of its immunity from the attacks of burrowing animals, and the fact that it does not shrink or crack.

Apparently, in the Mississippi Valley, no use has been made of the large clam-shell dredges which are the chief reliance for levee construction on the Pacific Coast. The largest of these machines have buckets with a capacity of 6½ cu. yd., and booms up to 240 ft. in length; they can handle all classes of material with ease, placing it from 300 to 400 ft. from the point where it is excavated. The writer has seen the surprising statement that "a canal with a base width of 123 ft. is practically the limit for economic construction with the floating dredge equipment now built", this comment referring to dipper-dredges.

In completing the Knights Landing Cut previously referred to, floating clam-shell dredges excavated a cross-section 6 000 sq. ft. in area, and with a bottom width of from 400 to 500 ft., without rehandling any material. By rehandling half the material, it is possible to excavate a canal of approximately double this width.

It may be because of the lack of adequate equipment that levee standards, generally, in the Mississippi Valley, are quite inferior to those in California. The Sacramento River West Side Levee District, for example, protecting the river frontage of Colusa Basin, has adopted a general standard showing a 20-ft. top width, an 8-ft. freeboard, and a volume exceeding that proposed for Dayton, and in general for work along the Mississippi River, by about 40 per cent. The writer recently saw some equipment which had been used for levee construction at Dayton, consisting of a bucket operating on a cable line suspended across the river from crude wooden towers, the whole apparatus appearing about as obsolete as a "dinosaur". He was told that the contractor had been getting more than 20 cents per cu. yd., and had "gone broke".

The channel improvement and levee construction work of the Sacramento River West Side Levee District, done by large clam-shell and suction dredges, has cost about 40% of the foregoing figure at Dayton, though conditions are hardly comparable.

It may also be possible that the cost of flood control, by levees and channel improvement as compared with detention reservoirs, in the

Miami Conservancy District, is unfavorably affected by the lack of some features which are more or less standardized for large dams, such, for example, as protection on exposed slopes. Experience on the Pacific Coast at least has indicated that thick earthen embankments can be completely destroyed by wave wash in a short time, possibly within the limits of the maximum time of exposure at an essentially fixed elevation which may occur in some of the Miami detention reservoirs. The writer does not intend this in any way as a criticism of the very thorough and carefully prepared plans for the Miami work, but rather intends to indicate that, with conditions as they are on the Pacific slope, the cost of a given measure of flood control by detention reservoirs and costly dams, as compared with the same measure of control by channel improvement and levees, may be relatively greater than for the Miami Conservancy District. Mr. Tibbetts.

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THE SUBSIDENCE OF MUCK AND PEAT SOILS IN SOUTHERN LOUISIANA AND FLORIDA

Discussion.*

By William H. Kimball, M. Am. Soc. C. E.

William H. Kimball,† M. Am. Soc. C. E. (by letter).‡—This paper deserves careful study by those engineers who have to deal with the reclamation of peat and muck soils, and they will follow with interest the continuation of the observations. Mr. Kimball.

The paper and its discussion show that engineers are justified in examining critically some of the previously published conclusions regarding the probable settlement of muck soils after drainage.

The writer is somewhat familiar with Florida drainage work, as he has been in charge of the Vero Drainage District since 1913, is familiar with the investigations made there under Mr. Okey's direction, and believes that the statements show the true conditions for that area. The muck of the Vero District, however, is of shallow depth compared with other Florida projects, and is not as representative of what may be anticipated as are the investigations in the Everglades

The paper and its discussion have made evident the great variation in the character of soils referred to as muck and peat, and emphasize the importance of a careful soil analysis in each case.

In the writer's opinion, Mr. Okey's paper is most timely and valuable, and the serious results that may arise from failure to anticipate the subsidence of muck and peat soils after drainage and cultivation are forcibly presented.

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* Discussion on the paper by Charles W. Okey, Assoc. M. Am. Soc. C. E., continued from January, 1918, *Proceedings*.

† Davenport, Iowa.

‡ Received by the Secretary, January 29th, 1918.

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STRESS MEASUREMENTS ON THE HELL GATE ARCH BRIDGE

Discussion*

By Isidore Delson, Assoc. M. Am. Soc. C. E.

Mr. Delson.

Isidore Delson,† Assoc. M. Am. Soc. C. E.—Several years ago, the Bridge Department of New York City completed the work of strengthening the end spans of the Williamsburg Bridge across the East River. In connection with this work, a great many strain observations were made with the Howard extensometer, in co-operation with the U. S. Bureau of Standards.

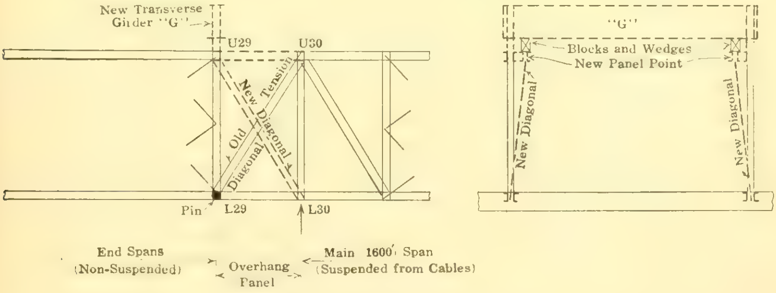

FIG. 8.

The speaker desires to describe here especially one series of observations which seem to him of particularly striking interest, inasmuch as they actually assisted in the diagnosis of a perplexing situation, and pointed out the safe method of procedure in a difficult operation.

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* Discussion of the paper by D. B. Steinman, Assoc. M. Am. Soc. C. E., continued from January, 1918, *Proceedings*.

† New York City.

Mr. Delson.

As indicated in Fig. 8, the end span trusses were supported in the lower chord, at Panel Point *L* 29, by 10-in. pins, by which the reaction was transmitted to the main, that is, suspension, span of the bridge through the panel triangle, *L* 29-*U* 30-*L* 30, containing the tension diagonal, *L* 29-*U* 30. As a part of the reconstruction, it was required to relieve these pins of their loads, to remove the pins, and then replace them by others of greater diameter.

At each truss a new panel triangle (*U* 29-*L* 30-*U* 30), containing the compression diagonal, *U* 29-*L* 30, was built out from the main span. The vertical end posts, *U* 29-*L* 29, of the end span trusses were connected to a new overhead transverse girder, *G*, which was supported by cast-steel blocks and wedges on the new panel points.

The relief of the pins was effected by wedging up the girder, *G*, from the new points of support, and the end spans were thus made to hang from that girder. As the old tension diagonals were being relieved of tension, the new diagonals were being compressed.

Extensometer points had been established on the old tension diagonal, and, also, on the new members before their erection.

It was determined by computation that the girder, *G* (and the trusses hung from it), would have to be wedged up ¾ in., in order to relieve the pins of the dead load re-action. However, when this wedging was effected, the pins absolutely refused to budge. The wedging was then increased to 1 in., and still the pins could not be made to move. The contractor apparently saw no other way but to continue this wedging process, and he was permitted to go as high as 1⅜ in., but without success.

All operations were followed up with extensometer observations on the members affected, but particularly on the diagonals. The results of these observations convinced the engineers of the Department that the contractor was on the wrong tack. Accordingly, the wedging-up process was stopped, and the condition was restored to the first established ¾-in. stage. Then the pins were removed by cutting them in halves. On their removal, there was not the slightest sensible dislocation of the members assembled on them, which verified the fact that no more nor less than the actual load on them was taken off.

The reason that the pins could not be rammed or pulled out was simply that they were rusted and scored too badly.

The following are the results of the extensometer readings for one of the old tension diagonals, and one of the new compression diagonals, at the Manhattan side, in the several stages of loading. These results are the averages of all readings in cross-section, of which there were six in the old diagonal and five in the new diagonal.

Old (tension) diagonal, *L* 29-*U* 30.—Cross-section, 98 sq. in., gross.—Computed dead-load stress in member at time of initial readings, 11 500 lbs. per sq. in.

Mr. Delson.

Apparent relief of stress.—Averages of six readings in cross-section.

Stage of wedging..	¾ in.	1 in.	1⅜ in.	¾ in.	After removal of pin.
"Relief", in pounds per square inch..	11 300	13 600	16 600	11 500	11 600.

New (compression) diagonal, *U* 29-*L* 30.—Cross-section, 148 sq. in.—Computed stress for dead-load reaction, 6 400 lb. per sq. in.

Apparent stresses.—Averages of five readings in cross-section.

Stage of wedging..	¾ in.	1 in.	1⅜ in.	¾ in.	After removal of pin.
Compression, in pounds per square inch.	6 500	7 700	10 500	6 650	6 300.

Attention is called, not only to the close agreement of the computed stresses with those disclosed in the ¾-in. stage, but also to the fact that, after the pins were removed, there was no change in the stresses of the members, showing that just the exact amount of wedging had been applied.

It should be noted that the series here presented is rather exceptional, and that such good results may not always be expected from the extensometer; but, even where results are not so satisfactory, they, as a rule, would be close enough to help greatly in arriving at a correct judgment of conditions for all practical purposes.

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CONSTRUCTION PROBLEMS OF THE MANHATTAN-BRONX, AND LEXINGTON AVENUE SUBWAY JUNCTION AND QUEENSBOROUGH TUNNEL CONNECTIONS

Discussion.*

By Messrs. John Hays Myers, Robert Ridgway, and Henry H. Quimby.

Mr. Myers

John Hays Myers,† Assoc. M. Am. Soc. C. E.—Mr. Quimby has pointed out that the water-proofing of the Queensborough Station arch beneath 42d Street was omitted, although it was shown on the contract drawings. An effort was made to water-proof this arch according to the contract drawings, but it was finally concluded that it was not feasible.

On pages 1903 and 1904‡ of the paper, the author has described the method of excavating and placing the concrete for the station arch. As there described, this arch was built generally in alternate bands, and had it been possible to obtain a water-proofing compound which would not have emitted fumes to any great extent, it might have been possible to water-proof, say, the 1st, 3d, 5th, etc., bands. It might also have been possible to water-proof the haunches of the 2d, 4th, 6th, etc., bands; but the speaker has never known of a practical solution of the problem of how to water-proof the closures. As he sees the problem, it would be necessary to place the water-proofing and then build the arch beneath it. Considerable thought having been given to water-proofing this arch, it was decided, as the author states, to omit it. However, the concrete of the arch was placed as close as possible to the rock. Numerous grout pipes were placed, and whatever space remained between the

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* Discussion of the paper by George Perrine, M. Am. Soc. C. E., continued from January, 1918, *Proceedings*.

† New York City. Previous discussion by Mr. Myers appeared in *Proceedings* for January, 1918.

‡ *Proceedings*, Am. Soc. C. E., November, 1917.

Mr. Myers. concrete and the rock was filled with grout. Later, the surface of the concrete was completely removed from the soffit of the arch by using pneumatic hammers, and a dense and well-troweled coat of plaster, containing some water-proofing compound, was applied. Since this work was done, a part of the arch has been removed in order to permit the construction of a passageway or ramp connecting the Queensborough and Diagonal Stations. This has permitted some water to flow into the Queensborough Station, but this condition, of course, has no connection with the water-tightness of the Steinway arch which, considering all the conditions, is fairly tight.

Mr. Ridgway. ROBERT RIDGWAY,* M. AM. SOC. C. E.—It is interesting to note that the work described in this paper was one of the most complicated and difficult of the eighty or more sections of construction included in the new Dual System of Rapid Transit for New York City. The estimated value of the work described by the author is about $3 100 000, the cost of the whole Dual System for construction being estimated at approximately $293 000 000, and for equipment approximately $70 000 000.

Before the connection between the present four-track subway operating under Park Avenue and the new four-track subway under Lexington Avenue was definitely located, careful studies of a number of other locations were made, notably those at Union Square, at 33d Street, and at 40th Street. Notwithstanding the fact that the construction and real-estate cost of the 40th Street location was estimated to be less than that for any of the others, it was more objectionable from an operating standpoint, largely on account of the sharp reverse curves between stations. The connection extending from Park Avenue below 40th Street to Lexington Avenue at 43d Street was finally selected as being the best, all things considered. It has become locally known as the "Diagonal Connection" because it crosses diagonally the site of the old Grand Union Hotel south of 42d Street and the New York Central Railroad property north of that street. The new Grand Central subway station is on this diagonal line. The curves into Park and Lexington Avenues are placed, with reference to the station, so that the trains are either slowing down for the stop or gathering headway, and therefore no reduction of speed is required on account of these curves.

The construction of the connection between the old and new subways was made extremely difficult by the necessity of maintaining the constant operation of trains on perhaps the most intensively operated railroad in the world. In rush hours a train passes on one of the four tracks every 30 sec., and the interval between the ten-car express trains at that time is 1 min. and 48 sec. The subway now carries about 1 400 000 passengers daily, of whom probably 1 000 000 pass the work described in the paper. The head-room over the trains is limited, and there is little side clearance. For these and other reasons the work had

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* New York City.

Mr. Ridgway.

to be carried on outside of the present structure. It was necessary, however, to occupy the tracks for certain operations, such as the placing of the columns and girders which are inside of the old subway structure. This work was done in the early morning hours, when the express trains were not running, and the local trains were operated on a 7-min. headway, as stated by the author.

The two north-bound tracks of the old structure, where the new work passes under it, were originally in a concrete-lined tunnel. This tunnel has been changed into a steel bridge, without interrupting train operation. In a number of instances the columns supporting the new tracks were set in shafts excavated in the rock, some of these shafts being stoped up from the new tunnel below. The difficulties are little realized except by those who have an intimate knowledge of the work. Certainly, the million passengers who were carried safely every day had little conception of what was going on about them. There is an old saying that accidents do not occur where they are expected; that is, because the dangers are realized and measures are taken to guard against them. That there was no accident of a serious nature indicates an intelligent understanding of the problems involved, and it speaks well for the careful attention to the details of the work by the engineers and contractors, and for the methods which they devised and followed. Much credit is due to the contractor's organization under the direction of Robert A. Shailer, M. Am. Soc. C. E., Tunnel Engineer for the Rapid Transit Subway Construction Company, and particular mention should be made of Mr. Perrine, the author of this paper, and of the General Superintendent, Thomas McCormick, who inaugurated and worked out many of the ingenious methods which were used so successfully in the work. The speaker would also add a word of appreciation of the services of the men who designed the work, of the Division Engineer in charge for the Public Service Commission, John H. Myers, Assoc. M. Am. Soc. C. E., and of his two assistant engineers, Mr. Stephen Schmidt and Melville S. Miller, Assoc. M. Am. Soc. C. E., who deserve the highest commendation. The fact that the work has been successfully carried to its present state of practical completion and that everything has come together so well indicates, not only the watchfulness and ability of the field engineers and contractors, but the excellent co-operation between them. Of course, honest differences of opinion occurred, and there were many discussions as to whether a detail of the work should be done in this way or in that way, but there was good team work, and the speaker believes the engineers and contractors have a wholesome respect for each other. In fact, without this team work he is sure the results would have been far less satisfactory.

Many will remember the tragic history connected with the construction of the present Park Avenue subway tunnels. There was an

Mr. Ridgway. explosion of a magazine in front of the Murray Hill Hotel in 1902, which caused much loss of life and damage to property. Following this a rock slide occurred in the easterly one of the two tunnels, which carried with it the fronts of several buildings on the east side of Park Avenue between 37th and 38th Streets, and, later, the contractor, the late Ira A. Shaler, M. Am. Soc. C. E., was mortally injured by a fall of rock from the roof of one of the tunnels, an accident which terminated the promising career of an able engineer who had accomplished great things.

When demolishing an old structure, it is always a satisfaction to find that it was honestly built, and this may be said of the concrete lining of the Park Avenue tunnels previously mentioned, which was cut out in connection with the new construction. In order to test its strength, two samples were cut out and sawed into 6-in. cubes. In taking the samples, an attempt was made to select concrete which appeared to be of a quality not as good as the average in the structure. When these samples were tested, one developed a compressive strength of 3 940 lb. per sq. in., the other did not break at the capacity of the machine, equivalent to about 4 250 lb. per sq. in. This concrete was about 13 years old. The timber which was used in temporarily supporting the rock in the old tunnels, and which was then built into the concrete, was very sound, and some of it was used in the new construction for temporary blocking.

The author mentioned the fact that the lattice girders taken from the Second Avenue Elevated Railroad in connection with the third-tracking of that structure were used for temporarily supporting the street decking. It is interesting to note that these girders had been in use in the elevated structure for more than 35 years, and were in good enough condition to carry the new burden placed on them. In view of the present difficulty of getting new steel, it is likely that further use will be found for them.

Mr. Quimby. HENRY H. QUIMBY,* M. AM. SOC. C. E.—Although this paper makes its special appeal to the contracting and field branches of the Profession, it is of very great interest to the designing engineer also, for a knowledge of the latest and most scientific methods of construction is necessary to the making of intelligent, feasible, and successful plans.

All who had the privilege of visiting the work during its progress were much impressed with the serious character of the contractor's task, and the ingenuity with which the construction problems were solved. The work looked ticklish, and evidently required much more than ordinary care, in order to avoid disaster. The visitor could not fail to appreciate, also, the ingenuity of the designers of the structure—both as a whole and in detail—with its successful solution of

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* Philadelphia, Pa.

Mr. Quimby.

the perplexing questions imposed by the routing plans of the new transit lines; thus the work is a remarkable achievement, both on the part of the engineers of the Public Service Commission and on the part of the contractor's engineers.

A noticeable feature of the paper is the evidence it contains of the cordial spirit of co-operation that prevailed between the contractor and the administrators of the contract. The fact is shown also in Mr. Myers' contribution to the subject, and is emphasized in Mr. Ridgway's discussion; all of which confirms the theory that the owner's engineer should regard the contractor, not as an enemy to be contended against, but as an associate to be co-operated with, for both desire the same thing—a first-class job, with safe and speedy completion.

The opportunity afforded by the demolition of an old engineering structure to learn something of the real results of construction methods is always appreciated, and, in the case of the old tunnel in Park Avenue, it was gratifying to see both the evidence of thoroughness in the efforts of its builders, and the fact of the complete success of the grouting operation—more gratifying than the revelations of demolition sometimes are.

The paper states that the contract provided for water-proofing above the arch over the station, but, after excavation had advanced, it was decided to omit it, and the arch was grouted and water-proofed inside. Apparently, the substituted method was not entirely successful, for work that has been going on there in cutting grooves, embedding drainage pipes, and plastering, seems to have been stopped, although there is still considerable leakage. What method of water-proofing above the arch was contemplated in the contract, and why was it abandoned; and is still another effort to be made to reduce the seepage?

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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ICE DIVERSION, HYDRAULIC MODELS, AND HYDRAULIC SIMILARITY

Discussion.*

By M. O. Leighton, M. Am. Soc. C. E.

M. O. Leighton,† M. Am. Soc. C. E. (by letter).‡—The author is to be commended for his experimental work. Ice jams at power-plant intakes are of too common occurrence, and the interruptions to service or the necessity for supplemental power occasioned thereby result in large financial loss and inconvenience. The fact that so many men of experience differ so widely as to the best methods of handling ice is in testimony of the diverse conditions met in different localities. Therefore, identification of general principles that will apply either directly or in modified form to all conditions is much to be desired. Mr. Leighton.

Mr. Groat's experimental principle is based on a separation of current direction between the upper and the lower parts of the stream section. By a series of submerged baffles he diverts the lower rather than the upper part of the stream into the diversion canal intake. By suitable modification of the channel he provides for an increase, or at least prevents a decrease, in the down-stream velocity of the upper portion of the moving water. The natural question that will occur to many readers is "What will happen to these transverse channels in the bottom of the main stream in the case of rivers that transport débris? Will they not be filled and their effectiveness thereby be eliminated?"

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* This discussion (of the paper by Benjamin F. Groat, M. Am. Soc. C. E., published in December, 1917, *Proceedings*, and presented at the meeting of January 2d, 1918), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Washington, D. C.

‡ Received by the Secretary, January 15th, 1918.

Mr. Leighton. The foregoing question is very practical. The majority of streams in the United States carry more or less débris. Even in the regions of clear streams, like Northern New England and the far Northwest, a large aggregate quantity of material is rolled along on the bottom of stream channels. This material, being too coarse or too heavy to enter into suspension, is precisely the type that might be expected to lodge in these transverse channels and gradually fill them up. It is true that there might be some cases in which the lateral velocity generated in these transverse channels would keep the channels clear, but in such event Mr. Groat's device would become an efficient instrument for the diversion of large quantities of gravel, etc., into the diversion canal, which gravel, under normal conditions, would continue its course down stream. Thus, the canal operator would have to determine whether freedom from ice troubles for a few days in the year would be preferable to an all-the-year-round deposition of gravel and other material in his canal. Presumably, the losses and inconvenience arising from the former would eventually be far less than those from the latter.

The writer does not find that Mr. Groat has included this matter of débris in his discussion, and hopes he will do so in his closure. It may be helpful to mention briefly the general conditions governing the transportation of débris in running water. Much work has been done, under the direction of the United States Geological Survey, at the hydraulic laboratory of the University of California, by Dr. Grove Karl Gilbert and Edward Charles Murphy, M. Am. Soc. C. E., the results of which have been published.*

A stream transports material in three ways:

(*a*) By Sliding or Rolling.—Débris so transported is that which is too coarse or too heavy to be raised by the current, but which is not heavy enough to resist the forward movement of the water;

(*b*) By Saltation.—Débris so transported moves by leaps or jumps. It is sufficiently light to be picked up by the current and carried for short distances—*i. e.*, from a few inches to a few feet—and then dropped on the bottom of the channel;

(*c*) Suspension.—Débris so transported is sufficiently light or fine to remain in suspension for longer periods. Some grades may drop to the bottom rather quickly when the current is checked, and some finer grades may remain in suspension almost indefinitely, even under quiescent conditions.

Of course, there is no sharp dividing line between the finer material that moves by suspension and the coarser material that moves by saltation. It is the material that is rolled along the bottom and that transported by saltation which might, and probably would, interfere

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* *Professional Paper No. 86*, U. S. Geological Survey, under the authorship of Dr. Gilbert.

Mr. Leighton.

with the complete success of Mr. Groat's device. Some idea of the complexity of stream traction and the difficulties encountered in devising any method for controlling the transportation of débris may be gleaned from the following paragraph, quoted from Dr. Gilbert's paper previously cited:

> "The flow of a stream is a complex process, involving interactions which have thus far baffled mechanical analysis. Stream traction is not only a function of stream flow but itself adds a complication. Some realization of the complexity may be achieved by considering briefly certain of the conditions which modify the capacity of a stream to transport débris along its bed. Width is a factor; a broad channel carries more than a narrow one. Velocity is a factor; the quantity of débris carried varies greatly for small changes in the velocity along the bed. Bed velocity is affected by slope and also by depth, increasing with each factor; and depth is affected by discharge and also by slope. If there is diversity of velocity from place to place over the bed, more débris is carried than if the average velocity everywhere prevails, and the greater the diversity the greater the carrying power of the stream. Size of transported particles is a factor, a greater weight of fine débris being carried than of coarse. The density of débris is a factor, a low specific gravity being favorable. The shapes of particles affect traction, but the nature of this influence is not well understood. An important factor is found in form of channel, efficiency being affected by turns and curvature and also by the relation of depth to width. The friction between current and banks is a factor and therefore likewise the nature of the banks. So, too, is the viscosity of the water, a property varying with temperature and also with impurities, whether dissolved or suspended."

In the case of material rolled along the bottom or transported by saltation, it is manifest that grievous complications would arise in the application of Mr. Groat's device, and it can well be imagined, in view of the complexities cited in the paragraph just quoted, that no one can forecast precisely what would occur, at least in the present state of our knowledge of the subject. It is probable, too, that in very few situations would the actual events be similar in character. It appears to the writer, therefore, that this is one of the cases in which the performance of a model will differ materially from that of the full-sized prototype, unless the model is located so as to copy with exactness all the collateral conditions with respect to the transportation of débris. As it would be difficult, if not impossible, to copy such conditions on a model scale, it occurs to the writer that the first section of Mr. Groat's paper furnishes an excellent illustration of the probable fallacies in the last section.

Mr. Groat introduces a relatively new term, "transportivity", which he defines as the transporting capacity, of a river at a particular place, which is measured by the product of the width and the mean surface

Mr. Leighton.

velocity. We have long been accustomed to use the term "capacity" to indicate the maximum load that a stream can carry, and though this term is ordinarily applied to the load in suspension, in saltation, or that rolled along the bottom, the analogy is so clear between these and the load that a stream can carry by flotation, that it seems unfortunate to introduce a new term. "Surface capacity" or "flotation capacity" would, in hydro-mechanical considerations of this kind, follow precedent, and be entirely definitive and satisfactory.

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DISCUSSION ON FINAL REPORT OF THE SPECIAL COMMITTEE ON CONCRETE AND REINFORCED CONCRETE*

By Charles F. Marsh, M. Am. Soc. C. E.

Charles F. Marsh,† M. Am. Soc. C. E. (by letter).‡—In his suggested method of calculation for the design of reinforced concrete beams, Mr. Rhett§ has fallen into the old error of equating the moments of the horizontal safe resistance. Mr. Marsh.

It is hardly necessary to point out that such an equality seldom, if ever, exists in a reinforced concrete member.

The horizontal safe resistances in tension and compression must, of course, be equal to one another, and the couple formed by the action of these safe resistances must be equal to, or greater than, the imposed bending moment, but, unless the neutral axis is at the mid-point of the arm of the couple, it is obvious that the moments of the two resistances cannot equal one another.

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* Continued from January, 1918, *Proceedings*.

† London, W. C., England.

‡ Received by the Secretary, November 10th, 1917.

§ *Transactions*, Am. Soc. C. E., Vol. LXXXI, pp. 1153–1159.

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PAPERS AND DISCUSSIONS

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DISCUSSION ON FINAL REPORT OF THE SPECIAL COMMITTEE ON MATERIALS FOR ROAD CONSTRUCTION AND ON STANDARDS FOR THEIR TEST AND USE*

By E. Dow Gilman, Assoc. M. Am. Soc. C. E.

Mr. Gilman.

E. Dow Gilman,† Assoc. M. Am. Soc. C. E. (by letter).‡—Referring to page 2381,§ on the subject "Abrasion Test for Broken Stone or Broken Slag", the writer notes that the specifications for this test as adopted in 1908 by the American Society for Testing Materials have been adopted in the report of the Committee. These specifications provide that the sample to be tested shall consist, as nearly as possible, of 50 pieces of the broken stone, the total weight of which shall be within 10 grammes of 5 kilogrammes. Under the conditions thus stated, the sample may consist of broken stone the individual pieces of which may be of widely varying size and weight. That a sample composed of 50 pieces of nearly uniform size will give different results from those obtained with a sample composed of 50 pieces some of which are small and others large would seem to require no proof.

Several years ago the writer made abrasion tests on a shipment of trap rock. An attempt was made to check results by duplicating the tests on other samples taken from the same shipment. Three separate tests were made on as many different samples, each of which was carefully prepared according to the specifications just stated. Such varying results were secured that the writer was not satisfied to submit any one or the average of the French coefficients thus obtained.

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* Presented to the Annual Meeting, January 16th, 1918.

† Washington, D. C.

‡ Received by the Secretary, January 7t7h, 1918.

§ *Proceedings*, Am. Soc. C. E., December, 1917.

Mr. Gilman. New samples were prepared, each consisting of 50 pieces of the broken stone and with the added specification that no single piece should weigh less than 90 or more than 110 grammes, and that any piece of a shape noticeably different from the general shape of the entire lot should be eliminated. The total weight of the sample was within 10 grammes of 5 kilogrammes, as before. The results were remarkably more consistent than with the other samples, and were so close together that, considering the unavoidable factors in a test of this nature, one would be warranted in submitting an average as the probable coefficient of the material at hand.

The objection to this added clause is the care required to prepare a sample and the quantity of material required from which to take one. In spite of this objection, the writer is inclined to believe that, if results secured by the abrasion test have any practical significance whatever, the test must be worthy of the slight extra labor involved. It seems to be a question whether the operation of the Deval machine for more than 5 hours and the labor in washing and drying the sample before and after the test are worth the time and energy, if the results of two or more samples of the same material are not reasonably close. Even with the utmost care, the tests for abrasion, hardness, toughness, and cementing value, give results that are rough and that can be taken as no more than a preliminary guide in passing judgment on the usefulness of a material. With the limited use that at present is made of the results of these tests, it would be unwise to burden them with too many refinements, but the writer submits the suggestion here made in the belief that greater reliance can be placed on comparative results thus obtained. This fact is apparently acknowledged in the specifications for the abrasion test of gravel, immediately following, which, under Method No. 2, insures, at least to a degree, the uniformity of separate samples.

The writer regrets that the data secured in the tests which he made are not available, so that by actual figures he might show comparisons of the methods; but he believes that the point in question can be raised without these figures, and that the matter is worthy of confirmatory investigation, with possible modification in the outline of the test at some later date.

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PAPERS AND DISCUSSIONS

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DISCUSSION ON FINAL REPORT OF THE SPECIAL COMMITTEE ON STEEL COLUMNS AND STRUTS*

By Messrs. Henry Prichard, Gustav Lindenthal, and Charles Evan Fowler.

Mr. Prichard.

Henry S. Prichard,† M. Am. Soc. C. E. (by letter).‡—The Committee is to be congratulated on its fine presentation of the results of the tests conducted by the Bureau of Standards. As a progress report, it is admirable, but the writer thoroughly endorses the sentiments which Clement E. Chase, Jun. Am. Soc. C. E., has expressed, in a letter just received from him, as follows:

"In reading what the Column Committee of the American Society of Civil Engineers are to present next week as their Final Report, I fail to see why they should consider their task at an end. They seem to have answered so few of the questions that have been raised in recent years as to column action, and to have passed so lightly over what has been done in the past in the way of experiment, analysis and discussion. I think their concept of a Useful Limit Point a good one, getting away from the controversial elastic limit, but I do not see that they give any evidence that what they call the U. L. P. is the useful limit.

"I expect to get down to the meeting next week, and have been wondering what would develop there. I wish that there were some way of continuing the Committee in existence, changing its personnel if the old members are tired of their work, for it seems hard to get Special Committees appointed in the Society. It would not be possible to do much in the way of testing during the war, but some planning of the next series of tests could be accomplished, and there would not

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* Presented to the Annual Meeting, January 16th, 1918.

† Pittsburgh, Pa.

‡ Received by the Secretary, January 16th, 1918.

Mr. Prichard.

be the effect of calling this report the Final and best that can be done after nine years of deliberation. If you agree and think that anything could be accomplished by discussion of the Report, or letter, in time for action at the Annual Meeting, I wish you could see your way to start something."

If the Committee is continued, the writer would suggest that Mr. Chase be added to its membership.

The point in testing where the rate of deformation becomes double the elastic rate has been adopted by the Committee as useful for practicable purposes and termed the "Useful limit point". "Double rate of deformation point" would be a better name, as it is accurately descriptive and does not commit the Committee to a characterization of the significance of the point as an indication of strength.

It has not been shown that the metal in a structural member ceases to have structural value when the rate of deformation of the member becomes double the elastic rate. In fact, Test No. 102, used by the Committee to illustrate the determination of the point where such a rate of deformation occurs, shows that, at the cost of a slight permanent set, the column became seemingly elastic to a higher point.

As regards specimen tests, the results tabulated by the Committee do show that the averages or means of the "Useful limit points" or "Double rate of deformation points", as the writer prefers to call them, of the coupons of the material of which the columns are composed, indicate, approximately, the ultimate strength of those columns which have a slenderness ratio of $\frac{l}{r} = 50$. The average ultimate strength of the thirty-three columns compared was 32 670 lb. per sq. in., though the average of the means of the "Double rate of deformation points" of the specimens was 32 080 lb. per sq. in.; and in no case was the ultimate strength of the columns less than the mean of the "Double rate of deformation points" by more than $3\frac{1}{3}$ per cent. This close relationship, which the report of the Committee shows, between the mean of the "Double rate of deformation points" of the specimens representative of a column, and the ultimate strength of the column, is a valuable contribution to engineering knowledge; but there remain many important questions, some of which can probably be answered by a study of the results of past experiments. The work of the Committee could be continued with advantage to the Profession.

Mr. Lindenthal.

GUSTAV LINDENTHAL,* M. AM. SOC. C. E. (by letter).†—This final report, giving the results of investigations and tests continued through seven years, will no doubt be regarded by structural designers as an authoritative guide in the proportioning of steel columns of such

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* New York City.

† Received by the Secretary, January 9th, 1918.

Mr. Lindenthal.

forms and in such cases as those to which the conclusions of the Committee are applicable.

The Committee was entirely justified in giving warning (page 2452*) that in considering the safe working value for a column it is necessary to take account of a number of uncertain and sometimes unknown factors. The Committee then enumerates fourteen such factors, divided into three groups (Material Condition of Loading, and Use). One factor, however, is not mentioned, and, like any of the others, it may have a deteriorating effect on the strength of the column under certain conditions; that is, the factor of the rivet holes when the column section is made up of different steel shapes riveted together into one column.

The rivet holes in columns quite frequently do not match accurately, notwithstanding the usual reaming to bring the holes to a fit. When the section is made up of three or more thicknesses, the holes in the inside plates, after reaming, may be oblong rather than round. The rivet, after driving and upsetting, may fit the hole tightly near each rivet head, but not always in the middle of the rivet. Moreover, the diameter of the rivet after cooling may be slightly smaller than the rivet hole. Most so-called tight rivets can be pushed out of the holes easily after one or the other rivet head is cut off. It cannot be claimed, therefore, that the rivets fill the holes so completely as to equal the solid metal before the holes were punched or drilled out. The rivet in the hole, also, frequently has scale on it, forming a hard film without strength. If that film is only $\frac{1}{2000}$ in. thick, then the rivet would be $\frac{1}{1000}$ in. smaller than the hole. Even with good workmanship, the fit for part of a tight rivet is more frequently less than $\frac{1}{1000}$ in. It is evident that rivet holes weaken a compression section as well as a tension section.

A plate, for instance, 12 in. wide and 1 in. thick, with four rivet holes $\frac{3}{4}$ in. diameter, on a horizontal section has a net section of 9 sq. in., which is its value for tension; but, for compression, the universal practice is to assume full 12 sq. in. as resisting the compressive stress. Have we any good reasons or tests anywhere to show that this assumption is justified?

It is obvious that the rivet hole must flatten before the metal in the rivet can participate in the compressive strength of the cross-section. It means (assuming a modulus of elasticity of 30 000 000) that the unit stress on the steel of the net cross-section must exceed 30 000 lb. before the rivet hole will flatten $\frac{1}{1000}$ of its diameter and before the rivet can take up a share of the compressive strain in the column, which, by that time, would be 22 500 lb. per sq. in. on the unperforated cross-section. The elastic limit of the steel will thus be passed on the net section long before it is reached in the unperfor-

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* *Proceedings*, Am. Soc. C. E., December, 1917.

Mr. Lindenthal. ated cross-section. Failure of the column by crushing or by buckling may thus be initiated in the over-stressed metal of the net section, and thus the low compression value based on the cross-section of riveted columns may be explained.

If this reasoning is correct, then the cross-section of a column is weakened in proportion to the rivet holes. That view has induced the writer, in his practice, to formulate the rule that the compressive stress shall be computed, not on the cross-section of the column, but on its net section, similar to the practice for riveted tension members. It is certainly on the side of greater safety, more particularly for the reason that failure of a steel frame structure (designed by the usual specifications), if loaded to destruction, would surely come first through the buckling of the compression members before any tension member would give way. The general belief that our framed steel bridges have a factor of safety of from 3 to 4 needs to be corrected. Frequently, it is not more than 2, but that includes the dead load. It is an ample margin for heavy structures, but hardly enough for lighter ones.

The writer has attempted a series of tests, with the object of clearing up this point of the weakening of columns by rivet holes, and for these has used rolled steel pipe sections, some unperforated and others perforated and the holes filled with rivets. The tests were made at the laboratory of the United States Bureau of Standards in Pittsburgh, but were not concluded. Such tests, however, should be continued until this question is definitely cleared up.

One of the most remarkable points brought out in the tests by the Committee is the great difference in the compressive strength of the Bethlehem **H** sections, referred to in the report as Sections 5, 5*A*, and 5*B* (Tables 15 and 19). That the U. L. P. should be 34 700 for the light section and only 19 700 for the extra heavy section of the same type (page 2452*) and for the same slenderness ratio (50), may be astonishing until we consider that the lower temperature at which the lighter section was very probably finished in rolling, as compared with the heavier section of the same type, must have a great influence on its value as a column. The lighter section is thus provided with a hard skin, possibly not more than $\frac{1}{20}$ in. thick, which is stronger than the metal underneath. That harder metal has a higher elastic limit, and thus can better resist the fiber strains from bending and buckling before final collapse. This view derives confirmation from the fact mentioned by the Committee (page 2438*) that in short lengths and for the same ratio of l to r (when the metal is exposed almost solely to block action) the differences in compressive strength disappeared.

The recommendation of the Committee that the testing of steel columns should be continued is well founded. We need to know more about the behavior of riveted column sections as compared with solid

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* *Proceedings*, Am. Soc. C. E., December, 1917.

Mr. Lindenthal.

sections of the same size. Measurement with the extensometer would show whether the compressive strain in columns is uniform for the entire length or whether the steel is stressed higher in the plane of the rivet holes. To establish this fact satisfactorily, the rivet spacing should not zig zag, but, experimentally, be on straight lines at right angles to the axis of the column. Such measurements should be made and compared on solid, rolled, unperforated, tube sections, and on others which have been perforated.

The definition and establishment of the U. L. P. (useful limit point) by the Committee is commendable and worthy of general adoption. Also, the use of round figures for compressive unit stresses (similar to the practice for tension unit stresses) in place of the senseless refinement (by 10 and 20 lb. per sq. in., as given in some tables) derived from the too pedantic use of compression formulas.

Mr. Fowler.

CHARLES EVAN FOWLER,* M. AM. SOC. C. E. (by letter).†—The Committee deserves more than a perfunctory vote of thanks for the wonderful devotion its members have shown in this most essential experimental work. Yet it is apparent that the scope of the inquiry must be broadened if future investigations are to reach the desired result.

There must be a determination of the essential details of built-up columns necessary to develop the greatest possible percentage of main sections; a determination of the principal riveting, together with the effect of riveting as respects the deduction for rivet holes; a means of procuring high steel of a uniform quality; and, lastly, an accurate means of determining the stresses due not only to live and dead load, but including impact, secondary stresses, temperature stresses, and initial stresses in the steel, to the end that there may be used a very much higher unit stress than the one proposed, thus reaching an economy and efficiency in bridge design from which engineers have departed so widely in the past twenty years.

When the writer was Bridge Engineer of the Hocking Valley Railway, in 1887, the pendulum was just beginning to swing back from the era of light loads and high unit stresses, which had resulted in bridges of the lightest type, where "the pins only held by the grace of God, and where the wind stresses had to slide down the end posts." The loading then beginning to be used was thought to be phenomenal—two 92.3-ton consolidation engines and unit stresses below 10 000 lb. per sq. in. were discussed. During the period from 1890 to 1898, in which the writer was Chief Engineer of the Youngstown Bridge Company, the pendulum swung far, and Cooper's E-40 and other heavy loadings came into vogue; and though engineers still clung to their factors of

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* New York City.

† Received by the Secretary, January 26th, 1918.

Mr. Fowler. safety, unit stresses as low as 6 000 or 8 000 lb. per sq. in., based on factors of ignorance, were used on the primary members of bridges.

Thus, up to the present, has been kept up the increase of loadings and the reduction of unit stresses, until engineers have wandered far from that efficiency which they must have under the new economic and trade conditions that are dawning. Engineers must know the stresses with certainty, they must have the best and most uniform high steels, so that they may safely use the highest logical unit stresses.

During the middle Eighties the Forth Bridge was built, and there was used in the compression members a high steel of from 76 160 to 82 880 lb. per sq. in., ultimate strength, with a unit stress, for the great circular compression members, 8 and 12 ft. in diameter, of from 15 680 to 16 800 lb. per sq. in., as shown in Table 24. This was in accordance with Continental practice and with the general recommendations of this Committee, but greatly in advance of the units proposed.

TABLE 24.—FORTH BRIDGE STRESSES, IN LONG TONS, SEPTEMBER 5TH, 1884.

Member	DEAD LOAD.		LIVE LOAD.		WIND LOAD.		TOTAL.		
	Stress.	Tons per square inch.	Stress.	Tons per square inch.	Stress.	Tons per square inch.	Stress.	Tons per square inch.	Pounds per square inch.
Bottom, 12 ft.	2 282	2.8	1 022	1.2	2 920	3.5	*6 224	7.5	16 800
Top tension	2 253	4.4	997	2.0	544	1.1	3 794	7.5	16 800
Vertical, 12 ft.	1 550	3.3	705	1.5	1 024	2.2	†3 279	7.0	15 680
Diagonal struts, 8 ft.	802	4.1	167	0.8	414	2.1	‡1 383	7.0	15 680
Diagonal ties	754	4.6	186	1.2	194	1.2	1 134	7.0	15 680
Horizontal wind Br.	80	0.9	5	0.1	265	3.0	350	4.0	8 960
Vertical wind Br.	42	0.5	169	2.0	108	1.3	319	3.8	8 512
Center girder, top	337	2.4	303	2.2	182	1.4	822	6.0	13 440
Center girder, bottom	330	2.3	301	2.1	247	1.8	878	6.2	13 890

* 830 sq. in. † 468 sq. in. ‡ 198 sq. in.

NOTE.—Same units for both tension and compression.

Comparing these sensible unit stresses with those which engineers, at the time, were evolving by the laborious use of the Rankine or Gordon formulas, one can at least begin to see the futility of obtaining a great variety of compressive unit stresses for the various members of the same structure and each one carried out to practically the last pound with ludicrous accuracy. The almost simultaneous proposing of straight-line formulas by Edwin Thacher, M. Am. Soc. C. E., and by Thomas H. Johnson, M. Am. Soc. C. E., caused a great feeling of relief to bridge designers, but never have they entirely departed from

Mr. Fowler.

a certain amount of hair-splitting accuracy in the design of compression members, so that now one must rejoice because the Committee has failed to promulgate its new formula, $20\,000 - 100\,\frac{l}{r}$ in favor of flat unit stresses, even though one may not agree with these values.

The effort to establish a "Useful Limit Point" does not, in the writer's opinion, tend toward the desideratum, in that one must fix the unit stresses at the highest possible safe value, when finally all the facts are known. Hence, it would seem advisable to fix the U. L. P. at the point where the record first departs from a straight line, or an absolutely safe value to which unit stresses may more closely approach. Then, again, in purchasing steel for compression members, it would seem to be more logical to specify the tests to be made in compression, to give a certain ultimate compressive strength and the corresponding yield point in compression.

Some valuable light might be thrown upon the variation between thick and thin metal, by testing several pairs of columns, from which ⅛ in. or so of the hard outer skin had been planed, thus proving to what extent the greater percentage of hard skin in the thin sections was responsible for the higher units.

The tests of columns of tubes, with and without rivet holes, or rather rivets, recently made by Gustav Lindenthal, M. Am. Soc. C. E., might be profitably amplified in order to decide as to the necessity for deducting rivet holes. The attention of designers is called to Mr. Lindenthal's discussion of this Report in which he proves conclusively the necessity for such deduction, and also to the Committee's tacit acknowledgment of this factor of overstress in rivet lines, by its decision to make the rivet spacing in the test columns closer than is usual in practice, to prevent the buckling of the (over-stressed) material between rivet holes. This is set forth in the first paragraph of page 2418.*

Further investigation should include a trip of a sub-committee to Europe, to glean all possible facts of value from Continental practice and to learn their methods of producing a more uniform output of steel.

The future programme of tests should cover, not only columns of the usual types with the usual detailing and the various end conditions, but also the eight forms, or test-size columns approximating them, which are probably the best, from a theoretical viewpoint: the old Phœnix; the old Keystone; the Gray column, with proper details; the ordinary box, and the Lindenthal "double box"; the Forth Bridge cellular circular; the Eads Stave Tube; and the writer's cellular octagonal, as described in his discussion† of the paper by O. H. Ammann,

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* *Proceedings*, Am. Soc. C. E., December, 1917.

† *Proceedings*, Am. Soc. C. E., January, 1918, p. 271.

Mr. Fowler. M. Am. Soc. C. E., entitled "The Hell Gate Bridge and Approaches of the New York Connecting Railroad over the East River in New York City." These forms are shown in Fig. 7.

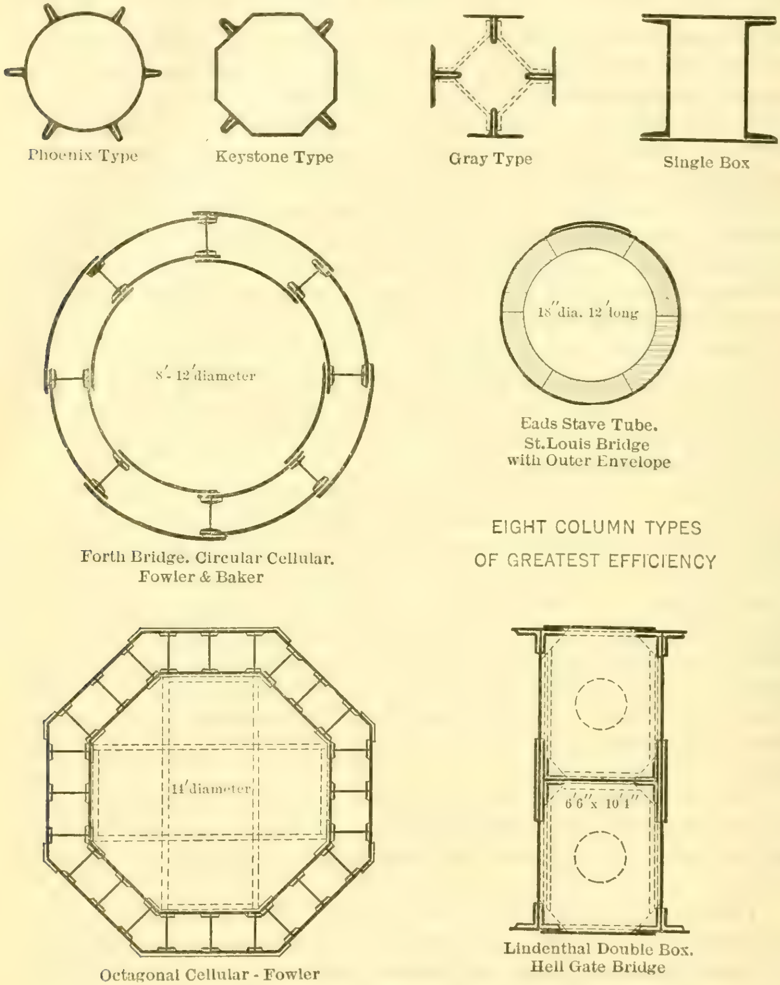

FIG. 7.

The tests made by the engineers of the Forth Bridge are of interest in this particular connection. Mr. Baker

"tested a piece of ordinary stove pipe, 4 in. in diameter and 2 ft. long, made of sheet iron only about a fortieth of an inch in thickness, and found it stood, without buckling, a compressive stress of 15.9 tons per sq. in.; whereas one of the Britannia Bridge rectangular cells, 18 inches

Mr. Fowler.

square and 8 ft. long, made of plates and angles half an inch thick, crippled under a stress of 13.6 tons, or say 15 per cent. less stress than that sustained by the piece of stove pipe. If flat plates, as much as half an inch in thickness, behave so badly in a rectangular cell only 18 in. square, it is hardly necessary to speculate as to what would be the case in tubes 12 ft. square, which would be the size required for the Forth girders."

The statements recently made, on high authority, that the rapid depletion of the raw materials for steel making would probably result in such abnormally high pries for steel within the next thirty years as practically to prohibit the construction of great bridges, should cause us to consider very carefully any proposed reduction of unit stresses. The column formula of the American Railway Engineering Association, $16\,000 - 70\,\frac{l}{r}$, between the limits of 28 and 120, with a unit stress of 14 000 lb. per sq. in. below 28, should certainly be adhered to until there are sufficient data to enable engineers to equal or surpass the units used abroad, or as herein shown by the Forth Bridge records.

Though engineers, for some years, have been preparing their designs on a factor of safety of practically two on the elastic limit, they must, in the writer's opinion, arrive at definite results or limits, both as to stresses and strength of members, and use an even smaller factor of safety, after having learned the lessons of efficiency which are being forced upon them.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications.

DISCUSSION ON PROGRESS REPORT OF THE SPECIAL COMMITTEE ON THE REGULATION OF WATER RIGHTS*

By LeRoy K. Sherman, M. Am. Soc. C. E.

Mr. Sherman.

LeRoy K. Sherman,† M. Am. Soc. C. E. (by letter).‡—In connection with the Progress Report of the Special Committee on the Regulation of Water Rights, the writer wishes to offer some comments with special reference to water-power rights.

These observations apply to conditions which came to the writer's notice as a member of the State Rivers and Lakes Commission of Illinois. In that State as well as other Central and Eastern States, where the common law applies, the riparian owner owns the bed of a river to the center of the stream. The water power is an appurtenant of the land. If the river is not a public or a United States navigable stream, the entire control and ownership of the water power is the sole property of the riparian owners. If the stream is a State or United States waterway, the State or Federal Government, or both, exercise primary supervision, inasmuch as the riparian owner must first obtain permits from the Government before he can build dams or other water surface regulating structures. This negative supervision by the use of permits is the only control exercised by the public over the natural resource of water power.

In most instances the riparian rights or lands affected by a potential water power are divided among several owners, and no power development is possible without the will and consent of each individual owner.

In these days, when coal production and transportation are vital problems before the Nation, we are confronted with the anomaly of

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* Presented to the Annual Meeting, January 16th, 1918.

† Chicago, Ill.

‡ Received by the Secretary, January 17th, 1918.

Mr. Sherman. available and useful water power running to waste. This condition does not come from any disinclination on the part of capital to make the necessary investment. The development of any water power may be, and often is, blocked by the will of one individual holding an insignificant part of the riparian rights. He is the "dog in the manger".

Regardless of the use to which water may be put, the control of water by the individual leads to economic waste and public injustice. The common law, so far as the water rights are concerned, was an adoption which does not fit with the streams in America. However, we have inherited the common law on water rights, and it appears to be impossible to get rid of it. The next course is to provide a means whereby the law will not result in a perversion of justice. The means suggested is to "apply the right of eminent domain to all water powers". This principle has been applied to some extent in many States through the so-called "Mill Act", whereby the right is given to condemn lands for the development of water power to operate public grist-mills. At the time of this legislation the grist-mill was the only public utility operated by water power. To-day the generation of electric energy by public service companies for lighting and power is the most valuable application of water power. The law of eminent domain cannot be applied, except for public use or benefit. Certainly the application of such power by public service corporations whose rates are regulated by the State is just as much of public use and benefit as are grist-mills, railways, or drainage districts, all of which have the right to condemn the land necessary for their existence.

Incidentally, the public control of water power brings up another proposition which has been much discussed before State public utility commissions; that is the valuation of undeveloped potential water power. On such public streams, or on navigable streams, as require a State or Federal permit for the erection of a dam or the diversion of water to generate power, the writer takes the position that the riparian owner does not possess any value in, and is not entitled to any compensation for, such potential water power. Any value of such potential power is the property of the State, by virtue of the special permit or grant to the riparian owner for his construction privilege.

Likewise, if the law of eminent domain is applied to non-navigable streams, the value of any potential water power must be the property of the State, and not the property of the riparian owner, as no utilization can be made, and hence no value exist, except by the act of the State.

Mr. C. R. Van Hise* has well stated the equity of this position in the words "A resource which originates from a wide area, but is available at a particular point, is the property of all the people concerned". The logic and justice of this position is illustrated in another way: The development of power at any point on a stream, whether by special license or permit from the State or not, is a special privilege because the riparian owner just below that point is deprived from exercising the same back-water privileges as those existing before his up-stream neighbor made the development. Mr. Sherman.

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* "Conservation of Natural Resources."

The "hit-or-miss" policy of power development in sections of a stream governed and limited by the extent of an individual's riparian holding is destructive and inefficient for the utilization of all the power of the stream.

The potential value of an undeveloped water power has sometimes been computed on the basis of the capitalized difference in cost of production of power by steam and by the water power in question. If this value is the sole property of the riparian owner, the public is deprived of any benefits of the natural resource of water power, and the right of eminent domain for such ownership is questionable.

If the power of a stream is to be developed to its maximum, and with the greatest efficiency, three things are necessary: State or Government approval of location, the right of eminent domain, and the principle that potential water power value is the property of the State.

MEMOIRS OF DECEASED MEMBERS

Note.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

HENRY AUGUSTUS HERRICK, M. Am. Soc. C. E.*

Died December 14th, 1917.

Henry Augustus Herrick was born on November 26th, 1861, in Brooklyn, N. Y. His parents, Henry Walker Herrick and Clarissa Harlow Parkinson, moved to Manchester, N. H., when he was four years old. He was educated in the public schools in Manchester, and was graduated from the High School at the age of nineteen.

His first work after graduation was with the Amoskeag Manufacturing Company, at Manchester, in connection with the design, construction, and equipment of cotton mills. He was later, in succession, engaged in similar work at the Methuen Mills, Methuen, Mass., at Willimantic, Conn., with F. P. Sheldon, Mill Engineer, Providence, R. I., and at the Schuylerville Mills.

In 1890 he went to Spokane, Wash., where he designed and supervised the construction of the dam and power station which is still in operation.

On January 14th, 1891, Mr. Herrick was married and went to Great Falls, Mont., where he designed and supervised the construction of the Black Eagle Falls Dam and power plant for the Boston and Montana Smelter.

In the latter part of 1895 he became associated with Dean and Main, Engineers, and was engaged in the design and supervision of construction of many textile and other industrial plants, and, with the dissolution of this firm in 1907, he continued his association with the writer.

The most interesting, valuable, and effective work was done by Mr. Herrick in the last 10 years of his life, during which he had charge of the design and construction of some of the largest and best hydro-electric developments in the country, namely, the Rainbow Falls development and the Great Falls development, on the Missouri River near Great Falls, Mont., the Thompson Falls development, on Clarks Fork of the Columbia River, at Thompson Falls, Mont., and he was just nearing the completion of his work on the Holter development, near Helena, Mont., when he was stricken by heart failure and died immediately. All these developments formed a part of the system of the Montana Power Company, and aggregated about 250 000 h. p.

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* Memoir prepared by Charles T. Main, M. Am. Soc. C. E.

During the time that the foregoing work was in progress, and between the ending of one and the beginning of another undertaking, he made many examinations and reports on other projects, and acted as Consulting Engineer on several.

Mr. Herrick had developed a systematic analysis of dams, based on his many years of close study and experience in designing such structures. All the many fundamentals, such as geological formation, seepage, drainage, upward pressure, shock and dissipation of energy due to overflow, flood conditions, etc., received proper consideration in his analysis.

His early training in design and construction enabled him to design the buildings for power stations in a most acceptable manner, and he mastered the electrical problems with great ease.

He was a great student and a fine mathematician. He was one of the best types of self-educated engineers. His character was of the highest, and his dealings with men above and below him were always characterized with fine courtesy and uprightness.

His principal recreation was trap and target shooting, hunting, and fishing, and he took as much pleasure in anticipation of outings as in the rare actual experiences which his busy life allowed to him.

He was a member of the Boston Society of Civil Engineers, the Engineers Club, of Boston, the Fresno Club, of Fresno, Cal., the Silver Bow Club, of Butte, Mont., and other societies.

Mr. Herrick was elected a Member of the American Society of Civil Engineers on May 7th, 1890.

GRANT ROHRER, M. Am. Soc. C. E.*

Died December 12th, 1916.

Grant Rohrer, son of Major Jeremiah Rohrer and Mary Redsecker Rohrer, was born in Lancaster, Pa., on October 18th, 1864. His family was of Swiss origin, and settled in Pennsylvania about 1732.

Mr. Rohrer's early education was received at Lancaster; he was graduated from the High School in 1880, and spent the next five years reading law and in miscellaneous studies.

His first engineering work was on the construction of two Western railroads: First in the Engineering Department of the Kansas, Nebraska and Dakota Railroad, and then as an Assistant in the Construction Department of the Kansas City, Wyandotte and Northwestern Railroad.

In May, 1888, he was appointed Assistant Superintendent of Construction on the Abrams Creek Branch of the West Virginia Central and Pittsburgh Railway, now the Western Maryland Railroad. This branch was a difficult piece of heavy mountainous construction connecting the Big Vein Coal Mines at Elk Garden, W. Va., with the main line in order to supplant a long inclined plane. The necessary grades exceeded 3%, and there were numerous 16° curves and a switch-back.

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* Memoir prepared by R. H. Hood, M. Am. Soc. C. E.

Mr. Rohrer and the writer were thrown together a great deal on this construction, and were room mates at Elk Garden. The business and personal association between them lasted until Mr. Rohrer's death, nearly 30 years later, and had a very material influence on the lives of both.

On the completion of the Elk Garden work and some mine surveys in that vicinity, Mr. Rohrer went to Alabama to examine and report on some coal and iron ore lands.

In 1890 he was Assistant Superintendent of Construction on 30 miles of the Ohio Extension of the Norfolk and Western Railroad until its completion.

He then returned to West Virginia to become Superintendent of the H. G. Davis Coal and Coke Company, at Thomas, W. Va., which mines were under the same interests as those that controlled the Elk Garden work he had done 5 years previously.

In 1897 he became Superintendent of the New York Office of R. H. Hood, Engineer and Contractor. This office was established by Mr. Rohrer and was very successful.

In 1899, he and the writer went to London to investigate the advisability of opening an office there, but reached the conclusion that the Boer War would be the cause of an extended depression in that market.

During the greater part of the last 20 years of his life, Mr. Rohrer was located in New York City where he built many structures and carried on a successful contracting business. He was also interested in several lines of manufacturing.

Mr. Rohrer never married. Three brothers and two sisters survive him. His closest business associates were Charles Meads and Allen N. Spooner, Members, Am. Soc. C. E., Mr. W. G. Cooper, and Dr. E. W. Caldwell.

He and the writer made tenders on the Roosevelt Dam in Arizona, the anchorages and superstructure of the Manhattan Bridge, the Narrows Siphon, for the Board of Water Supply, City of New York, and other large undertakings.

At the time of his death Mr. Rohrer was a Director and officer of numerous corporations, some of which were the R. H. Hood Company, Charles Meads and Company, Allen N. Spooner and Son, Inc., F. G. Fearon Company, Homer Corporation, etc.

He took the keenest interest in politics, and although an ardent Republican, was broad in his views and actions. His bright and cheery disposition and droll wit won him popularity among his associates, and a large portion of the later years of his life was devoted to the interests of his numerous friends. He had a pleasing personality, possessed great tact and diplomacy, and seemed to derive much pleasure from the help he extended to others.

His death occurred suddenly on December 12th, 1916, from heart disease while sitting in his office chair, and was a great surprise to his relatives and friends, as he had never shown any symptoms of disease and had always been particularly free from sickness. He was buried with Masonic rites at Lancaster, Pa.

At the time of his death he was a member of the following Societies: Pennsylvania Society, of New York, Lodge No. 43, F. and A. M., Lancaster, Pa., Chapter No. 43, R. A. M., Lancaster, Pa., Lancaster Commandery No. 13, K. T., Lancaster, Pa., and Zembo Temple, A. A. O. N. M. S., Harrisburg, Pa.

Mr. Rohrer was elected a Member of the American Society of Civil Engineers on July 1st, 1909.

JOHN EDWARD SWANKER, M. Am. Soc. C. E.*

Died October 20th, 1917.

John Edward Swanker, the son of Augustus F. and Louisa Swanker, was born at Schenectady, N. Y., on July 4th, 1865. He received his early education in the schools of Schenectady, and then entered Union University, from which he was graduated in the class of 1887, in the Department of Civil Engineering.

Immediately after his graduation, Mr. Swanker entered the employ of the Rochester Bridge and Iron Works, of Rochester, N. Y., where he remained for about eight years. While at Rochester, he was engaged in drafting, designing, and estimating, and also had considerable experience in bridge shop practice and management, thus gaining much of that complete knowledge of American bridge building methods which has marked the career of many of the men who began their engineering experience under the late John F. Alden, M. Am. Soc. C. E.

Later, this association was continued in the Engineering Department of the Hilton Bridge and Construction Company, of Albany, N. Y., where Mr. Swanker remained until the plant was closed by the American Bridge Company, which had acquired it, in 1900. While with the Hilton Bridge and Construction Company, he was engaged on many of the larger bridges built by that company, and also had experience in the Sales Department. When the plant was taken over by the American Bridge Company, he became Manager and Engineer, which position he retained until the plant was closed.

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* Memoir prepared by James Watt, Assoc. Am. Soc. C. E., and Walter R. Marden, M. Am. Soc. C. E.

About the time work was discontinued at the Hilton Plant of the American Bridge Company, Mr. Swanker was elected General Manager of the Tees Side Bridge and Engineering Works, Limited, of Middlesbrough, England, and held that position for six years, during which time the business was re-organized in accordance with American methods and the output doubled, while the cost of maintenance was reduced more than one-third.

During this period, many important structures were fabricated and erected under the personal direction of Mr. Swanker, several of which elicited favorable comment in the English technical press at the time. The project of the Khushalgahr Bridge in India was considered almost impracticable, but was successfully carried through to completion. The railroad bridge over the Tees River at Stockton-on-Tees was replaced by a new structure which was floated into place without interruption of traffic; as were also the transfer bridges at the North and South Shields Docks, near Newcastle-on-Tyne, under very difficult tidal and local conditions.

On the completion of his engagement with the Tees Side Bridge and Engineering Works, Limited, Mr. Swanker returned to the United States and, after a short period of rest, became Engineer for David Lupton's Sons Company, of Philadelphia, Pa. Later, he was General Manager for W. N. Kratzer and Company, of Pittsburgh, Pa., after which he entered the Engineering Department of the Ferguson Steel and Iron Company, of Buffalo, N. Y., where he remained until his death.

Mr. Swanker was quick and decisive in forming engineering judgment, and will be remembered by his business associates as a man of untiring zeal and ambition, marked with sterling integrity and uprightness of character.

He was a member of the Protestant Episcopal Church and, at the time of his death, was a member of Yonnondio Lodge No. 163, F. and A. M., of Rochester, N. Y., Temple Chapter No. 5, R. A. M., of Albany, N. Y., York Preceptory, of Newcastle-on-Tyne, England, and Ismailia Temple, A. A. O. N. M. S., of Buffalo, N. Y.

While in England, Mr. Swanker was a member of the British Iron and Steel Institute; he was also a charter member of the Efficiency Society of America.

He was married on March 25th, 1896, to Clara A. Sage, of Rochester, N. Y., who survives him.

Mr. Swanker was elected a Member of the American Society of Civil Engineers on May 4th, 1904.

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OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XLIV—No. 3

AMERICAN
SOCIETY OF
CIVIL
ENGINEERS
FOUNDED
1852

March, 1918

Published at the Headquarters of the Society, 33 West Thirty-ninth Street, New York,
the Fourth Wednesday of each Month, except June and July.

Copyrighted 1918, by the American Society of Civil Engineers.
Entered as Second-Class Matter at the New York City Post Office, December 15th, 1896.
Subscription, $8 per annum.

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OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852)

VOL. XLIV—No. 3

MARCH, 1918

Edited by the Secretary, under the direction of the Committee on Publications.

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TO CODIFY PRESENT PRACTICE ON THE BEARING VALUE OF SOILS FOR FOUNDATIONS, ETC.: Robert A. Cummings, Edwin Duryea, E. G. Haines, Allen Hazen, James C. Meem, Walter J. Douglas.

ON THE REGULATION OF WATER RIGHTS: F. H. Newell, W. C. Hoad, John H. Lewis.

TO REPORT ON STRESSES IN RAILROAD TRACK: A. N. Talbot, A. S. Baldwin, G. H. Bremner, John Brunner, W. J. Burton, Charles S. Churchill, W. C. Cushing, Robert W. Hunt, George W. Kittredge, Paul M. LaBach, C. G. E. Larsson, G. J. Ray, Albert F. Reichmann, H. R. Safford, F. E. Turneaure, J. E. Willoughby.

The Reading Room of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

HEADQUARTERS OF THE SOCIETY—33 WEST THIRTY-NINTH STREET, NEW YORK.

TELEPHONE NUMBER......................4600 Vanderbilt.
CABLE ADDRESS......................"Ceas, New York."

Vol. XLIV. MARCH, 1918. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

This Society is not responsible for any statement made or opinion expressed in its publications.

SOCIETY AFFAIRS

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MINUTES OF MEETINGS

OF THE SOCIETY

February 20th, 1918.—The meeting was called to order at 8:30 P. M.; Vice-President Nelson P. Lewis in the chair; Chas. Warren Hunt, Secretary; and present, also, 184 members and 27 guests.

Mr. V. T. Goggin, Contracting Engineer, Fred T. Ley and Company, Inc., described the construction of Camp Devens, at Ayer, Mass., illustrating his remarks with lantern slides and moving pictures.

Max E. Schmidt, M. Am. Soc. C. E., offered a resolution to the effect that the names of all Members, Associate Members, Associates, and Juniors of the Society, who may lose their lives in the service of the United States during the present war, be placed on a memorial tablet and displayed in perpetuity at a suitable place within the rooms of the Society.

On motion, duly seconded, the resolution was referred to the Board of Direction for consideration and such action as may be deemed proper.

The Secretary announced the following deaths:

Charles Webster Gay, of Lynn, Mass., elected Member, May 5th, 1891; died, February 1st, 1918.

Clarence Browning Vorce, of Farmington, Conn., elected Member May 2d, 1900; died, February 4th, 1918.

Adjourned.

March 6th, 1918.—The meeting was called to order at 8.30 P. M.; Director A. D. Flinn in the chair; Chas. Warren Hunt, Secretary; and present, also, 101 members and 6 guests.

The Chairman announced the appointment of Messrs. William J. Boucher, F. B. Marsh, C. E. Fowler, G. A. Griffin, and H. L. Hurd as Tellers to canvass the ballots on the proposed revision of the Constitution.

The minutes of the Annual Meeting, January 16th, 1918, and of the meeting of February 6th, 1918, were approved as printed in *Proceedings* for February, 1918.

A paper by Floyd A. Nagler, Jun. Am. Soc. C. E., entitled "Verification of the Bazin Weir Formula by Hydro-Chemical Gaugings", was presented by the author and illustrated with lantern slides. The paper was discussed by Frederic P. Stearns, Past-President, Am. Soc. C. E., who also showed some lantern slides. The Secretary announced that he had received written communications on the subject from Messrs. Clemens Herschel and D. A. Molitor. On account of the lateness of the hour it was decided not to read these discussions.

C. F. Brown, M. Am. Soc. C. E., who had intended to address the Society on the subject of unusual drainage problems in Utah, stated that the lantern slides on which his remarks were based had gone astray, and he would like to defer the presentation of the subject until a subsequent meeting.

The following report of the Tellers appointed to canvass the ballots on the proposed revision of the Constitution, was presented:

"March 6, 1918

"Total number of ballots received			2133
"Deduct:			
"Not entitled to vote		30	
"Blank		2	32
"Yes	546		2101
"No	1555		
	2101		

"Respectfully submitted,

"William J. Boucher
"F. B. Marsh
"C. E. Fowler
"G. A. Griffin
"H. L. Hurd."

The necessary affirmative vote of two-thirds of all ballots cast not having been received, the Chairman declared the revision lost.

The Secretary announced the following deaths:

OTTO SONNE, of New York City, elected Member, September 7th, 1887; died November 13th, 1917.

JOHN WATERHOUSE, of New York City, elected Member, October 4th, 1899; died February 20th, 1918.

AUGUSTINE WASHINGTON WRIGHT, of Los Angeles, Cal., elected Member, May 5th, 1886; died February 3d, 1918.

Adjourned.

OF THE BOARD OF DIRECTION

(Abstract)

January 14th, 1918.—The Board met at 10 A. M.; President Pegram in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Alvord, Craven, Davies, Fay, Flinn, Greiner, Harwood, Herschel, Hill, Humphreys, Kittredge, Khuen, Noble, Rights, Tillson, and Webster.

A Budget prepared by the Finance Committee was presented and referred to the incoming Board of Direction with the recommendation that it be adopted.

Director Flinn, Chairman of the Library Committee, presented a Report of that Committee for the year.*

Director Harwood, Chairman of the Publication Committee, reported progress.

Director Davies reported the receipt of an additional subscription of $2 500 from the Bethlehem Steel Company for carrying on the work of the Special Committee on Stresses in Railroad Track. The Secretary was instructed to express the thanks of the Society to the Bethlehem Steel Company, and to its President, Mr. Grace, for this gift.

Mr. Davies, Chairman of the Committee on Special Committees, presented a report.†

The report was accepted and its recommendations adopted.

A Progress Report was received from the Committee to Report on the Advisability of the Establishment of Student Branches.‡

The Minutes of the Meetings of the Executive Committee of November 1st, and November 27th, 1917, and January 9th, 1918, were presented, and the actions taken by the Executive Committee at these meetings concerning the War Revenue Act of 1917,§ War Committee of Technical Societies of Engineering Council, and with relation to the Draft of Engineering Students,‖ were approved.

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* See page 247.

† See page 244.

‡ *Proceedings,* Am. Soc. C. E., February, 1918, p. 144.

§ *Proceedings,* Am. Soc. C. E., November, 1917, p. 672.

‖ *Proceedings,* Am. Soc. C. E., December, 1917, pp. 759–760.

The Report of the Board of Direction prepared by the Executive Committee was presented and adopted for presentation to the Annual Meeting.*

The Secretary reported that the property of the Society at 220 West 57th Street, had been loaned to the Food Administration of the United States in accordance with authority of the Executive Committee, and under certain restrictions which had been agreed to by Mr. Hoover. The action of the Executive Committee in regard to the Society property was approved, with the thanks of the Board for its action.†

A report was received from the Committee to Recommend the Award of Prizes.

It was voted that the recommendations of the Committee be approved and the medals and prizes were awarded by the Board in accordance therewith.‡

The incoming President was authorized to appoint three delegates to represent the Society at a meeting of the National Security League to be held in Chicago, February 21st-23d, 1918.

A report of work accomplished by the Naval Consulting Board, signed by Alfred Craven and A. M. Hunt, representatives of this Society on that Board, was presented, and accepted with the thanks of the Board.§

Resolutions adopted by the Canadian Society of Civil Engineers (now the Engineering Institute of Canada) were presented and ordered printed in *Proceedings.*‖

Clemens Herschel was appointed as one of the representatives of this Society on the United Engineering Society for three years to succeed himself.

J. Waldo Smith was re-appointed to serve another term as one of the representatives of the Society on the Engineering Foundation.

The resignation of J. D. Galloway as one of the representatives of this Society on Engineering Council, on account of military service, was reported, and also that President Pegram had appointed Charles F. Loweth to fill his unexpired term.

Certain rules adopted by Engineering Council under which additional societies may become members of that body were considered. The following resolution was adopted:

"That the communication from the Secretary of Engineering Council be received, and that the Secretary of this Society be instructed to reply that this Society prefers to defer final action until a more definite scheme of financing be developed in harmony with the plans of the United Engineering Society, and that a Committee of this Society be appointed by the chair to confer with the United Engineering Society in the effort to develop a plan for financing."

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* *Proceedings,* Am. Soc. C. E., January, 1918, p. 24.

† *Proceedings,* Am. Soc. C. E., January, 1918, p. 9.

‡ *Proceedings,* Am. Soc. C. E., February, 1918, p. 110.

§ *Proceedings,* Am. Soc. C. E., January, 1918, p. 3.

‖ *Proceedings,* Am. Soc. C. E., February, 1918, p. 143.

The President subsequently appointed Messrs. Kittredge, Davies, and Hunt, as such Committee.

The Constitution of the Pittsburgh Association of Members of the American Society of Civil Engineers, which was formally organized November 27th, 1917, was presented and approved.

Messrs. Parker and Aaron were appointed counsel for the Society.

A letter was presented from William H. Wiley, M. Am. Soc. C. E., calling attention to the proposed formation of the American Academy of Engineers.

The following resolution was offered by Dr. Humphreys, seconded by Mr. Alvord, and adopted:

"*Resolved:* That it is the opinion of the Board of Direction of the American Society of Civil Engineers that such an organization as is proposed under the title of 'Academy of Engineers', if there is a field for its activities, should be organized under the initiative of the National Engineering Societies, and particularly that the membership of an Academy of Engineers should not be made up by self-appointment."

A letter was presented in behalf of General Crozier, of the Ordnance Department, thanking the Secretary for his patriotic efforts in supplying draftsmen for that Department.

A report of the Tellers to Canvass the Final Suggestions in the matter of the Nominating Committee, Messrs. Noble, Rights, and Flinn, was received and ordered presented to the Annual Meeting.*

Action was taken in regard to members in arrears for dues.

The resignations of 9 Members, 28 Associate Members, 2 Associates, and 7 Juniors, were accepted.

Ballots for membership were canvassed, resulting in the election of 8 Members, 38 Associate Members, 9 Juniors, and the transfer of 15 Juniors to the grade of Associate Member, and 1 Junior to the grade of Associate.

Thirteen Associate Members were transferred to the grade of Member.

Applications were considered and other routine business transacted.

Adjourned.

January 15th, 1918.—The Board met at 11.30 A. M.; Vice-President Webster in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Alvord, Fay, Flinn, Greiner, Hill, Khuen, Kittredge, and Noble.

A report from the Membership Committee was received and acted upon.

Adjourned.

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* *Proceedings*, Am. Soc. C. E., February, 1918, p. 111.

January 16th, 1918.—The Board met at 1 P. M., at the Headquarters of the Society, 33 West 39th Street, New York City, at the time of the Annual Meeting, as required by the Constitution (Art. VI, Sec. 7); President Talbot in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Alvord, Davis, Fay, Flinn, Herschel, Hill, Humphreys, A. M. Hunt, Kittredge, Ketchum, Khuen, Lewis, Noble, Pegram, Rights, Tillson, Wagner, and Webster.

A Budget for the year 1918 prepared by the Finance Committee of 1917, and which was recommended to the incoming Board for adoption, was presented and adopted.

The following Standing Committees of the Board were appointed: On Finance: George W. Kittredge, Chairman, Alex. C. Humphreys, George S. Webster, Frederic H. Fay, and Nelson P. Lewis; on Publications: Lewis D. Rights, Chairman, Frederick C. Noble, Andrew M. Hunt, John F. Coleman, and Milo S. Ketchum; on Library: Alfred D. Flinn, Chairman, Lewis D. Rights, Samuel T. Wagner, Richard Khuen, Jr., and Chas. Warren Hunt; and Committee on Special Committees: John W. Alvord, Chairman, George W. Tillson, and Edwin Duryea.

The President announced that the next business was the election of a Secretary.

Mr. Hunt retired.

Chas. Warren Hunt was nominated and unanimously elected Secretary.

Mr. Hunt was recalled and informed of his election.

It was ordered that the Annual Convention of 1918 be abandoned on account of the war.

The time was fixed for the next two meetings of the Board of Direction.

Adjourned.

March 12th, 1918.—The Board met at 10.25 P. M., immediately after the adjournment of the Membership Committee; President Talbot in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Humphreys, A. M. Hunt, Kittredge, Lewis, Pegram, Rights, Tillson, and Wagner.

Ballots for membership were canvassed resulting in the election of 13 Members, 51 Associate Members, and 15 Juniors, and the transfer of 7 Juniors to the grade of Associate Member.

Seventeen Associate Members were transferred to the grade of Member.

A Report from the Membership Committee was received and acted upon.

Adjourned.

SOCIETY ITEMS OF INTEREST

ENGINEERING COUNCIL

Definition Adopted February 21st, 1918

Engineering Council is an organization of National Technical Societies of America created to provide for consideration of matters of common concern to engineers, as well as those of public welfare in which the Profession is interested, in order that united action may be made possible. The organizations at present represented in Engineering Council are the American Society of Civil Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, known as the Founder Societies, and having a membership of 33 000.

General Statement As to Past and Proposed Activities of Engineering Council

Prepared by the Secretary and Approved by the Executive Committee

Engineering Council held its first meeting on June 27th, 1917. In the months which have elapsed, useful services have been rendered to the Government, to engineering societies, and to individuals, and progress has been made in perfecting Council's organization. Offices have been furnished free of charge in the Engineering Societies Building, New York City, the focus of engineering activities in America. A permanent executive officer, with the title of Secretary, has been engaged; he entered upon his duties on January 1st. Several important committees have been created, and have accomplished much.

On February 21st, 1918, the first annual meeting was held. The following officers were elected: J. Parke Channing, Chairman; Harold W. Buck, First Vice-Chairman; George F. Swain, Second Vice-Chairman; Alfred D. Flinn, Secretary. Committees were appointed as follows:

Executive Committee.—The Chairman, the two Vice-Chairman, D. S. Jacobus, Calvert Townley, and George J. Foran.

Finance Committee.—E. W. Rice, Jr., Chairman, Charles F. Loweth, Sidney J. Jennings, and D. S. Jacobus.

Rules Committee.—J. Parke Channing, Chairman, Clemens Herschel, Nathaniel A. Carle, and Irving E. Moultrop.

Public Affairs Committee.—Charles Whiting Baker, Chairman, George F. Swain, Benjamin B. Thayer, E. W. Rice, Jr., and Charles E. Skinner.

American Engineering Service.—George J. Foran, Chairman, George C. Stone, Alfred D. Flinn, Addams S. McAllister, and Edward B. Sturgis, Secretary.

War Committee of Technical Societies.—D. W. Brunton, Chairman, Arthur H. Storrs, Secretary, James M. Boyle, Nelson P. Lewis (American Society of Civil Engineers), Edmund B. Kirby (American Institute of Mining Engineers), A. M. Greene, Jr., R. N. Inglis (American Society of Mechanical Engineers), Harold W. Buck, Addams S. McAllister (American Institute of Electrical Engineers), Dana D. Barnum, E. C. Uhlig (American Gas Institute), Joseph Bijur, Charles A. Doremus (American Electrochemical Society), Louis B. Parks, Preston S. Milar (Illuminating Engineering Society), Christopher R. Corning, George C. Stone (Mining and Metallurgical Society of America), Henry Torrance, F. E. Matthews (American Society of Refrigerating Engineers).

Fuel Conservation Committee.—L. P. Breckenridge, Chairman, Ozni P. Hood, Secretary, Robert H. Fernald, Charles R. Richards, Charles L. Edgar, Carl Scholz, David Moffat Myers, Edwin Ludlow, and Harold W. Buck.

Patents Committee.—A Patents Committee, to investigate reforms in the United States patent system and in the use of experts in litigation wherein the validity of patents or other technical matters are involved, was also created, but the names of its members cannot yet be announced. The committee was instructed to co-operate with any committee of the National Research Council, and with committees of other technical societies organized for a kindred purpose.

Limitation of financial resources has been and still is one of the greatest handicaps. At the beginning of 1918, an appropriation of $16 000 by the United Engineering Society, contributed equally by the four Founder Societies, became available for the period ending October 31st, 1918. Although this sum provides for the expenses of the Secretary's office, for inaugurating several permanent lines of service, and for a few special items in connection with the War, it is far from adequate. Engineering Council is still forced to go slowly on work already undertaken, and to decline or defer other meritorious projects. That Engineering Council has accomplished as much as it has is due chiefly to the fact that individuals, societies, and Government bureaus have informally contributed services and means. Additional income must be had if Engineering Council is to bring to pass within a reasonable time many of the things rightfully expected of it for the benefit of professional engineers, the country, the Government, and the public.

Restriction of membership in Engineering Council to the four societies just mentioned is not intended. Quite to the contrary, it is planned and earnestly desired that other national technical societies shall become affiliated, thus making Engineering Council truly representative of the hundred thousand engineers in all branches of the profession throughout the United States. Conditions and methods for the admission of additional societies have been developed. Henceforth, a chief aim of Engineering Council will be to increase the number of member societies, and thus gain, not only an enlargement of its capacity for usefulness along its chosen lines, but also greater technical and financial support.

So extensive is the field of possible activity for Engineering Council that even yet it is unwise to set its bounds. Nevertheless, some of the proposed activities may now be outlined. Foremost among these is the fostering of a sense of solidarity throughout all divisions of the profession in all parts of the country, and increasing the sense of common interest and of the strength that results from unification. To this end, subordination to the general welfare of the preferences and pride of organizations and of persons may be necessary; but it is confidently expected that, even through difficult places, the right paths will be found. Patience and good sense will win full and effective co-operation. Publicity of a high order, but of a practical sort, must be devised in order that both engineers and the public may be informed, not only of engineering achievements in physical work, but also of the services which pertain peculiarly to engineers, in mental realms, those which they are performing and those which they should perform. Engineers and engineering must be made more comprehensible to the people up and down the land, and kept instructively and interestingly in the public prints. A most important service is the standardization of definitions, methods, requirements, and tests for all varieties of engineering materials and work. Others are the improvement of the methods and requirements of engineering colleges, the standardizing of the meanings and values of the degrees given to graduates, and the broadening of the engineer through knowledge of humanitarian subjects, in which other professional men take interest.

Mutual helpfulness in getting the right engineer for the empty niche of usefulness and in finding an empty niche for the unemployed engineer, or for the one seeking advancement, has for years been a need of engineering societies, widely voiced, especially by the younger men. Many endeavors have been and are being made to meet this need, with more or less success; but most of them have been limited. Engineering Council has already given this matter much thought, and has put it in the hands of the American Engineering Service, one of its Committees. To meet these demands this committee has been assembling in its offices in the Engineering Societies Building, New York, comprehensive lists and much detailed information concerning engineers in all branches of the profession. During the past few months, there have been supplied to Government departments and bureaus several thousand names of engineers, from which men have been selected to fill a great variety of positions in uniformed and civilian service for the Army, the Navy, and other branches of the

Government's activities in connection with the War, as well as for manufacturers and contractors engaged on Government war work. Hitherto, these war demands have absorbed most of the energies of this committee and its staff, but, incidentally, there have been accumulated great masses of live material which, in the near future, can be re-cast into a suitable mould of classification, and indexed for permanent use. On methods of classifying and indexing, the committee has already done not a little work. It is the intention to discover what has been done by others and to combine and strengthen all useful systems so as to secure the greatest benefits for engineers, for employers, and for local, State, and National governments. It is the aim, ultimately, to create a complete, skilfully classified catalogue of all American professional engineers. This body of information will have many obvious uses, as well as others that will be discovered.

It has become evident that, although numerous engineering societies are occupying limited fields efficiently, and although some of these fields are extensive, there are large sectors of the domain of the engineer which are either only weakly held, or are usurped by others. This condition has arisen partly from specializing tendencies, among societies as well as among individuals. Until the present time, there has been no central agency capable of entering these sectors and competent to speak for the profession at large; no duly constituted representative to learn of the share in local civic and governmental enterprises which should be the engineer's, to claim it for him, and to see that he gets it; no organization to harmonize the action of the profession on similar questions in different localities; no interpreter to the public of the engineer, his work, his ideals, and his methods; no body to develop meritorious projects for the general good of the profession or for the benefit of the public; no one constantly on guard to detect and oppose objectionable schemes and tendencies. To fill these gaps is the great aim of Engineering Council; not by demolishing any useful existing agencies, but by building these into a well-proportioned and thoroughly furnished structure. Of course, time will be required for establishing and perfecting such an organization, with its necessary local branches covering all the United States.

Engineers are organizers, and should be directing their abilities as such to the greater service of the nation. No better demonstration of the need of such a centralizing body as Engineering Council could be had than the multiplicity of existing engineering organizations, and especially the manifestation during recent months of this tendency to segregation exhibited in efforts to serve the Government in connection with the War. Order is slowly being brought out of this confusion, but, if Engineering Council could have been well established before the beginning of the War, it would have become at once the connecting link between the Government and engineers, securing results quickly, directly, economically, and in an orderly manner. While contributing its best endeavors to the winning of an early and complete victory, Engineering Council must be shaping its organization so as to be prepared to aid engineers in taking the leading part which must be theirs in the years following the conclusion of peace.

Unselfish service and mutual helpfulness must be the test requirements for all the undertakings of Engineering Council. Offensive political or business activities must be avoided, and the selfish aims of groups or individuals must not be fostered. If the work roughly outlined is carried forward in this spirit, no fears need be entertained for the profession's ethics, its honor, or the standing of the engineer in the community.

Compensation of Professional Engineers and Engineering Assistants on Railroads

In a communication, presented to the Railroad Wage Commission, in Washington, on February 28th, 1918, Engineering Council asks that consideration be given to the compensation of professional engineers and engineering assistants on railroads (as distinguished from locomotive enginemen and other operatives of engines), and presents the following arguments:

Engineers and engineering assistants have no union or similar organization to urge increases of salaries or betterment of conditions, as have the skilled and unskilled labor employees. Except in a few individual cases, no increase in compensation of technical employees of railroads has been made since 1914, but, within that period large increases have been granted to skilled and unskilled labor. Owing to the depreciation of the dollar, these technical employees, therefore, have suffered a great reduction in income. Applications for increases, even when based on the increased cost of living, have been refused on the ground that such men can be replaced and that they must stand war privation, although no such theory has been applied to the case of the trainmen, who, also, as individuals, can be replaced. As a class, neither trainmen nor technical employees can be replaced at present.

The following examples of discrepancies in compensation are given: Of thirty-one classes of railroad employees, concerning whom information is given in a letter from the Bureau of Railway Economics, quoting the Interstate Commerce Commission report for the year ending June 30th, 1915, twelve classes on the average received more, and eighteen classes less than the assistant engineers and draftsmen; those of the class receiving the highest pay (road passenger engineers and motormen) obtained nearly 100% more. Road freight engineers and motormen, and road passenger conductors were paid about 66% more; foremen, boilermakers, brakemen, firemen, and helpers received approximately the same pay as the assistant engineers and draftsmen. It is probable that, if figures for 1917 were available, they would be much lower in proportion.

Many railroad engineers, draftsmen, etc., who have secured industrial employment have thereby increased their salaries from 20 to 150%, but, of course, tables of averages, general statements, and specific examples must be considered in connection with many other data. Local conditions affect rates of pay. Railroad managements differ in their policies on this matter; during the past year and a half some have fully, or in a measure, met the conditions which have arisen. Rates of pay for steady employment with a railroad company cannot be compared directly with rates for industrial engagements, often of limited duration and involving extra expense.

In conclusion, attention is called to the fact that upon the intelligence, skill, and efficiency of the technical engineers the maintenance, operation, and progress of the country's railroad systems largely depend. The men deserve just compensation, and in order to inspire them to the services which will yield the highest benefits to the community, as well as to the railroads, they should receive liberal pay.

Report of Committee on Special Committees

"30 Church Street, New York,
"January 10, 1918.

"To the Board of Direction,
American Society of Civil Engineers,
New York, N. Y.

"Dear Sirs:

"Your Committee on Special Committees begs to submit a report on the work of the several Special Committees during the past year, as follows:

"The expenditures of all the Special Committees during the past year have been materially less than the amounts provided in the budget for their use.

"The following figures show the amounts appropriated, the amounts expended, and the balance unexpended, for each of the Special Committees:

"Special Committee on	Appropriated.	Expended.	Balance.
"Steel Columns and Struts..........	$2 400.00	$718.37	$1 681.63
Engineering Education	....	....	....
Materials for Road Construction....	800.00	214.22	585.78
Bearing Value of Soils............	959.25	291.97	667.28
Regulation of Water Rights........	450.00	40.00	410.00
Valuation of Public Utilities.......	250.00	....	250.00
Stresses in Railroad Track.........	5 253.91	2 812.07	2 441.84
Concrete and Reinforced Concrete (expenses carried over from previous years)....................	817.83	817.83	....
Totals....................	$10 930.99	$4 894.46	$6 036.53

"There may, however, be other accounts received from the Special Committees for payment after January 1st, which would be properly chargeable to last year's work, but in all probability such accounts, if any, will be very small.

"Of the work carried on by the individual Special Committees, we would report as follows:

1. On *Engineering Education.*

"We have received from Mr. Desmond FitzGerald, Chairman of this Special Committee, the following advice:

" 'I expect the final report of our Committee will come some time in the Autumn of 1918, and I will make a progress report at the annual meeting. Dr. Mann's special report is now completed, and will perhaps be started in the press during January. It is a great report, not in size, but in matter, and I expect will be epoch making and of great value for the schools. It has been greatly reduced in bulk, but covers the ground in a masterly manner.'

"This Special Committee asks for no appropriation, as the expenses, whatever they have been, have been borne by the Carnegie Foundation, by whom Dr. Mann was employed. We have understood that Dr. Mann has terminated his engagement with Carnegie Foundation and has taken up work elsewhere, so that the Special Committee can hardly look to Dr. Mann to complete its work, unless the subject is covered completely by Dr. Mann's report to which Mr. FitzGerald refers.

"2. On *Steel Columns and Struts.*

"The final report of the Special Committee is published in the December *Proceedings,* and the Chairman, Mr. Lewis D. Rights, asks for its discharge at the Annual Meeting. It seems to us that it would be a mistake to discharge this Special Committee at the Annual Meeting, and we think their final report should be accepted at the Annual Meeting, and the matter of final discharge of the Special Committee left in the hands of the Board of Direction for action at such time as the discussion of the final report is completed. Mr. Rights suggests that there may be expenses incurred in connection with the discussion and the closing of the work of the Committee, and asks for an appropriation for this purpose of $500, though he does not anticipate that this amount will be expended. In order, however, to reduce so far as possible the limits of expenditure, we recommend the appropriation of only $250, to be available in the event that it should be required for the completion of the work of this Special Committee.

"3. On *Materials for Road Construction.*

"The final report of this Special Committee is also published in the December *Proceedings,* and Professor A. H. Blanchard, Secretary of the Committee, advises that the Committee does not expect to be continued and makes no request for an appropriation for expenses for 1918. Our recommendation in reference to this Special Committee is that an amount of $100 be appropriated for any possible expenses which the Committee may incur in connection with the work arising from the discussion of the report, although it is probable that even this small amount will not be expended.

"4. On *Bearing Value of Soils for Foundations.*

"We have been in correspondence with Mr. Robert A. Cummings, Chairman of this Special Committee, and have also had a personal interview with him regarding the procedure of the Committee during the year 1918. Mr. Cummings is of the opinion (and we agree with him) that the work of this Special Committee is in such a condition that no special or particular benefit will be obtained by the Society by continuing the work of this Committee during the current year or until the termination of the war, and we recommend that there be no appropriation made for the work of this Special Committee other than a nominal amount of, say, $100 for such expenses as may possibly be incurred in keeping the Committee alive.

"5. On *Regulation of Water Rights.*

"Professor F. H. Newell, Chairman, has submitted a brief progress report, which will be presented at the Annual Meeting, and which indicates that little, if any, actual work has been done by this Special Committee. This report contains the following:

" 'It is recognized that progress must necessarily be slow, especially during this period when the minds of Engineers and of their associates are turned almost exclusively to war conditions.'

"He asks that the balance unexpended of the appropriation for 1917 remain available for 1918. Such an arrangement is contrary to all previous rulings of your Board. In our opinion, it is not likely that this Special Committee will be able to accomplish effective work during the duration of the war, and, in that case, we would recommend that a sum not exceeding $100 be appropriated simply with the idea that this Special Committee be kept alive until the termination of the war and for the payment of such necessary expenses as may be incurred in this process.

"6. On *Stresses in Railroad Track.*

"This Special Committee has continued its work during the past year and will submit a progress report at the Annual Meeting. We have had correspondence with Mr. Charles S. Churchill in relation to the needs of this Committee, and we are advised that the balance unexpended of the special fund contributed by the various steel manufacturers, together with the balance remaining in the hands of the American Railway Engineering Association, will be adequate to pay the expenses of this Committee's work during the year 1918, particularly as Professor Talbot indicates that the question of obtaining assistance to carry on the work, due to war conditions, is likely to curtail materially the extent of the work to be done. We recommend that this Special Committee be empowered to draw upon the special fund in the hands of the Society to the extent of the amount of money remaining to the credit of this Committee, in which case there will be no draft upon the general funds of the Society.

"The Chairman of this Special Committee, Professor A. N. Talbot, will unquestionably be chosen as the next President of the Society. We have communications from Mr. Charles S. Churchill, Mr. A. S. Baldwin, and Mr. W. M. Dawley, representing the membership of the Joint Committee of the American Society of Civil Engineers and the American Railway Engineering Association on Stresses in Railroad Track.

requesting that every effort should be made to retain Professor Talbot as Chairman of this Committee. We have also received intimation that Professor Talbot would be willing to retain the Chairmanship, and, in addition to his duties as President, perform the duties involved as Chairman of this Special Committee. We strongly endorse this request and heartily recommend to the incoming Board of Direction, that Professor Talbot be retained as Chairman of this Special Committee, so that the policy and general plan of the work may remain unchanged.

"Generally speaking, we feel that under the existing war conditions the active work of the Special Committees, remaining alive, should be curtailed to the greatest extent possible, not only to reduce the expenditure of funds of the Society, but in order to conserve the personal efforts of the members of the several Special Committees, many of whom are actively engaged in governmental work at this time.

"During the past year there has been referred to the Committee on Special Committees a request for the appointment of a Special Committee to investigate the matter of creosoted wood stave pipe for hydraulic and irrigation work. We have corresponded with a number of members whom it was suggested were particularly interested in this subject, and have received diverse replies from them. We recommend that the whole matter of appointment of such a Special Committee be referred, with all correspondence on the subject to the incoming Committee on Special Committees for further consideration.

"Respectfully submitted

"GEO. W. TILLSON
"W. L. DARLING
"J. V. DAVIES
"Chairman."

Report of Library Committee

"January 14th, 1918.

"TO THE BOARD OF DIRECTION
AMERICAN SOCIETY OF CIVIL ENGINEERS:

"Through changes in the management of the Society's affairs and its property during recent years, and especially during the year 1917, the provisions of the Constitution for a Library Committee have become almost a dead letter. Some of the duties are performed by the Secretary and the Board of Direction, and others have largely passed to the Library Board of the United Engineering Society. The whole matter of the year's events as to the Society's headquarters and its library are well covered in the Annual Report of the Board of Direction, prepared by the Secretary. It is, therefore, unnecessary to repeat a statement of these matters in a separate report.

"For the year 1917 the striking events are the removal from the Society's previous home in 57th Street to its new quarters in the Engineering Societies Building, the temporary use of the former headquarters by the Food Conservation Commissioner, the transfer of 67 000 volumes of the Society's library into the Engineering Societies Library, and the donation to the Cleveland Association of Members of the

American Society of Civil Engineers of 22 000 volumes which were duplicates of volumes already in the Engineering Societies Library.

"As to the library, the most important work now to be done is the complete amalgamation of the several collections of books into one well-arranged, thoroughly indexed, engineering library at the earliest practicable date.

"Respectfully submitted,

"GEORGE A. HARWOOD,
"LEWIS D. RIGHTS,
"J. V. DAVIES,
"CHAS. WARREN HUNT,
"ALFRED D. FLINN,
"Library Committee,
"BY ALFRED D. FLINN,
"Chairman."

ANNOUNCEMENTS

The Reading Room of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

April 3d, 1918.—8.30 P. M.—At this meeting George W. Fuller, M. Am. Soc. C. E., will give an informal talk on "Emergency Construction Work Due to War Conditions", illustrated with lantern slides. Mr. Fuller will outline the construction work necessitated by the War, with special reference to the building of cantonments; the preliminary organization; the urgent importance of proper engineering direction; the establishment of the Cantonment Division with head reporting directly to the Secretary of War; civilian assistance; the style of contract for construction, with its merits and defects; the work connected with water supply, sewerage, heating, lighting, roads, etc.; and will present some practical lessons taught by actual experiences with emergency work.

April 17th, 1918.—8.30 P. M.—Instead of the usual presentation and discussion of a professional paper, there will be substituted a joint meeting of engineers, at which the John Fritz Medal will be presented to J. Waldo Smith, M. Am. Soc. C. E., for "Achievement as engineer in providing the City of New York with a supply of water."

John J. Carty, Past-President, Am. Inst. Electrical Engineers, and President of the Board of Award will preside. Addresses will be made by the Hon. A. T. Clearwater and by Nelson P. Lewis, Vice-President, Am. Soc. C. E., and the medal will be presented to Mr. Smith by Ambrose Swasey, Past-President, Am. Soc. Mechanical Engineers and of the Board of Award.

Ladies are cordially invited to attend this meeting.

May 1st, 1918.—8.30 P. M.—A regular business meeting will be held, and a paper by J. A. L. Waddell, M. Am. Soc. C. E., entitled "The Economics of Steel Arch Bridges", will be presented for discussion.

This paper is printed in this number of *Proceedings.*

ANNUAL CONVENTION ABANDONED

The Board of Direction has decided that the Annual Convention of 1918 shall be abandoned, on account of War Conditions. Among the reasons for this action are: the absence of many members of the Society in the service of the country; the inappropriateness of social functions at this time; the limitation of transportation facilities; and the advisability of the practice of economy along all lines.

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction to the members who have made use of the resources of the Society in this manner has been expressed frequently, and leaves little doubt that if it were generally known to engineers that such assistance could be had, many would avail themselves of it.

On October 1st, 1916, the Library of the American Society of Civil Engineers ceased to exist as such, and was merged in the Engineering Societies Library, adding 67 000 volumes to the collection, which comprises also the former libraries of the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, and now has a total of 133 000 volumes and pamphlets. Containing, as the Library now does, the special collections mentioned, its scope is broadened, and, as it receives an unusually large number of technical periodicals, it is well equipped to continue the service formerly rendered by the Society Library.

The Engineering Societies Library offers this service at a cost which is trifling compared with the value of the time of an engineer who personally looks up such matters, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

It sometimes happens that references are found which are not readily accessible to the person for whom the search is made. In that case the Library is prepared to furnish photographic copies of the material at a small price per page. This method is particularly useful when there are drawings or figures in the text, which would be very expensive to reproduce by hand.

The Library is also able to provide translations of articles in foreign languages when desired.

Requests for searches, copies, translations, etc., should be addressed to the Director, Engineering Societies Library, 29 West 39th Street, New York City, who will gladly give information concerning the charges for the various kinds of service.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings.*

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion will be published as heretofore in *Proceedings,* and set down for presentation to a future meeting of the Society, and, on these, oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which from their mathematical or technical nature, in the opinion of the Committee, are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions only will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions.*

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 35 of the Year Book for 1917.

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association, Organized 1905.

Jerome Newman, President; Nathan A. Bowers, Secretary-Treasurer, 502 Rialto Building, San Francisco, Cal.

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Palace Hotel, on the third Tuesday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at noon, every Wednesday, at the Engineers' Club, 57 Post Street, where special tables are reserved for members and guests of the Association.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

Colorado Association, Organized 1908.

Robert Follansbee, President; L. R. Hinman, Secretary-Treasurer, 1400 West Colfax Avenue, Denver, Colo.

The meetings of the Colorado Association of Members of the American Society of Civil Engineers (Denver, Colo.) are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesday at 12.30 P. M., at Daniel's and Fisher's.

Visiting members are urged to attend the meetings and luncheons.

(Abstract of Minutes of Meeting)

December 8th, 1917.—The meeting was called to order at the Denver Athletic Club; Arthur O. Ridgway in the chair; L. R. Hinman, Secretary.

The minutes of the meeting of November 10th, 1917, were read and approved.

Mr. Thomas W. Jaycox, representative of the Association on the Joint Committee on Improvement of Roads adjacent to Denver, reported progress and outlined plans for future work of the Committee.

Mr. Charles W. Comstock, Chairman of the Committee on War Taxes, reported for that Committee. The subject was discussed by Messrs. Vincent, Jaycox, Houston, Field, and Hinman, and resolutions were adopted and ordered sent to the Society, the other Local Associations, and to the Colorado members of Congress.

Owing to the absence of Milo S. Ketchum, Chairman, the presentation of the report of the Committee on Student Branches of the Society was postponed until the next meeting.

Messrs. Jewett, Northam, and Olds were appointed as the Entertainment Committee for the next meeting.

Addresses were made by Messrs. J. M. Gaylord, Thomas W. Jaycox, and J. C. Ulrich on "Experiences of the United States Reclamation Service with Large Reservoir Outlets", "Experiences with Reservoir Outlets near Creede, Colo.", and "Experiences with Reservoir Outlets in the San Luis Valley, Colorado", respectively. These addresses were illustrated with lantern slides, and the subject was generally discussed by the members present.

Adjourned.

Atlanta Association, Organized 1912.

B. M. Hall, President; W. C. Spiker, Secretary-Treasurer, 1408 Candler Building, Atlanta, Ga.

Baltimore Association, Organized 1914.

Mason D. Pratt, President; Charles J. Tilden, Secretary-Treasurer, The Johns Hopkins University, Baltimore, Md.

Cleveland Association, Organized 1914.

Harry Fuller, President; George H. Tinker, Secretary-Treasurer, 516 Columbia Building, Cleveland, Ohio.

Detroit Association, Organized 1916.

T. A. Leisen, President; Clarence W. Hubbell, Secretary, 2348 Penobscot Building, Detroit, Mich.

The regular meetings of the Association are held on the second Friday of December, April, and October, the last being the Annual Meeting.

District of Columbia Association, Organized 1916.

A. P. Davis, President; John C. Hoyt, Secretary-Treasurer, U. S. Geological Survey, Washington, D. C.

Duluth Association, Organized 1917.

F. E. House, President; Walter G. Zimmermann, Secretary, Wolvin Building, Duluth, Minn.

The regular meetings of the Association are held at noon on the third Monday of each month (usually at the Kitchi Gamma Club), with luncheon, followed by a short business session and the reading of papers. Visiting members of the American Society of Civil Engineers can secure from the Secretary definite information relating to the meetings, at which they will be welcomed. The Annual Meeting is held on the third Monday in May.

(Abstract of Minutes of Meeting)

February 19th, 1918.—The meeting was called to order at the Kitchi Gamma Club; President F. E. House in the chair; W. H. Woodbury, acting as Secretary; and present, also, 22 members and 7 guests.

The Committee on the Organization of an Engineers' Club reported that a list of all the local members of the National Societies had been compiled, and suggested that an informal meeting be called of all the members of the Profession in Duluth and vicinity to discuss the organization of a club which would include all men engaged in engineering work. On motion, duly seconded, the suggestion was adopted, and the Committee was authorized to act accordingly.

The proposed revision of the Constitution of the Society was discussed, but no formal action by the Association was taken, the opinion, however, being strongly in favor of its adoption.

The discussion of the paper on "Sandstone Concrete", by Major T. F. McGilvray, which was presented at the January meeting, was opened by Mr. Clarence Coleman, and the subject was discussed by other members and guests present.

Adjourned.

Illinois Association, Organized 1916.

A. S. Baldwin, President; Edgar S. Nethercut, Secretary-Treasurer. 705 Michigan Ave., Evanston, Ill.

The regular meetings of the Association are held on the second Monday of March, June, September, and December, the last being the Annual Meeting. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary.

Louisiana Association, Organized 1914.

W. B. Gregory, President; Charles W. Okey, Secretary, Tulane University, New Orleans, La.

The regular meetings of the Association are held at The Cabildo. New Orleans, La., on the first Monday of January, April, July, and October.

Nebraska Association, Organized 1917.

George L. Campen, President; Homer V. Knouse, Secretary-Treasurer, 115 City Hall, Omaha, Nebr.

Regular meetings of the Association are held on the first Saturday of each month, except July and August, and at such places as may be appointed from time to time by the Executive Committee. The Annual Meeting is held in Lincoln, Nebr., on the second Friday in January.

An "Engineers' Round Table" is reserved daily for luncheons, at Courtenay's Restaurant, 17th and Douglas Streets, Omaha, to which all engineers are invited. Visiting members of the Society are especially urged to communicate with the Secretary when in the city.

Northwestern Association, Organized 1914.

P. E. Thian, President; Ralph D. Thomas, Secretary, 508 South First Street, Minneapolis, Minn.

The meetings of the Association are held bi-monthly, alternating between St. Paul and Minneapolis, on the third Friday of each month. Information as to the time and place of such meetings will be furnished on application to the Secretary.

Philadelphia Association, Organized 1913.

Henry H. Quimby, President; C. W. Thorn, Secretary, 1313 South Broad Street, Philadelphia, Pa.

The regular meetings of the Association are held at the Engineers' Club of Philadelphia, 1317 Spruce Street, on the First Monday in January, April, and October, the last being the Annual Meeting.

Pittsburgh Association, Organized 1917.

Richard Khuen, Jr., President; Charles M. Reppert, Secretary-Treasurer, 422 City-County Building, Pittsburgh, Pa.

The Annual Meeting of the Association is held on the first Monday in October. The time and place of other meetings are not fixed, but this information will be furnished on application to the Secretary.

(Abstract of Minutes of Meetings)

November 27th, 1917.—The meeting to organize the Association was called to order by Richard Khuen, Jr.; Charles M. Reppert, acting as Secretary; and present, also, 49 members of the Society.

The following officers were elected: President, Richard Khuen, Jr.; Vice-President, Robert A. Cummings; and Secretary-Treasurer, Charles M. Reppert.

A Constitution was prepared and unanimously adopted by the meeting, and the Secretary was ordered to submit a copy to the Board of Direction of the Society for consideration and approval.

A Sub-Committee, consisting of Messrs. Thomas Fleming, Jr., Paul Didier, and T. Sidney White, was appointed to prepare and submit a draft of By-Laws, and this Committee was instructed to report at a meeting of the Association to be called in two months.

On motion, duly seconded, it was decided to hold the next meeting of the Association on January 9th, 1918.

Adjourned.

January 9th, 1918.—The meeting was called to order at the Builders' Exchange Auditorium; President Khuen in the chair; C. M. Reppert, Secretary; and present, also, 38 members.

The minutes of the meeting of November 27th, 1917, were read and approved.

The report of the Committee, consisting of Messrs. Fleming, Didier, and White, appointed to draft By-Laws for the Association was presented. The report was discussed, and, on motion, duly seconded, the By-Laws as a whole and as amended were adopted.

The Secretary read a letter from the Chairman of the House Committee of the Engineers' Society of Western Pennsylvania relative to the availability of the auditorium in the Union Arcade Building as a place of meeting, and, after discussion, it was decided, on motion, duly seconded, to refer the question of arrangements for an auditorium to the Executive Committee.

The proposed revision of the Constitution of the Society was discussed by many of the members present. On motion, duly seconded, recommendations expressing the sense of the meeting in regard to a number of the provisions were adopted, and the Secretary was instructed to send an extract of the minutes of the meeting relative to this matter to the Secretary of the Society to be read at the Annual Meeting of the Society on January 16th, 1918, prior to the discussion of the subject.

On motion, duly seconded, the President was requested to make such use of the recommendations adopted by the Association as he might deem advisable.

President Khuen announced the appointment of Messrs. Fleming, Dilworth, and Talbot as a Committee on Activities.

On motion, duly seconded, it was decided to hold the next meeting of the Association during the month of February, at the call of the Executive Committee.

Adjourned.

Portland, Ore., Association, Organized 1913.

Philip H. Dater, President; C. P. Keyser, Secretary, 1147 East Yamhill Street, Portland, Ore.

St. Louis Association, Organized 1888 (Constitution Approved by Board, 1914).

J. A. Ockerson, President; C. M. Daily, Secretary-Treasurer, 34 East Grand Avenue, St. Louis, Mo.

The Annual Meeting of the Association for the election of officers and for the transaction of business, is held on the fourth Monday in November. Two meetings each year, for the presentation and discussion of technical papers, are held in the Auditorium of the Engineers Club of St. Louis and are open to members of the Associated Societies. Other "get-together" meetings are held regularly for dinner or luncheon on the fourth Monday of each month except July, August, and November.

(Abstract of Minutes of Meeting)

February 25th, 1918.—The 67th meeting was called to order at 6.30 P. M., at the American Hotel Annex; President Ockerson in the chair; C. M. Daily, Secretary; and present, also, 22 members.

The minutes of the 65th and 66th meetings were read and approved.

The Secretary read a letter from A. N. Talbot, President, Am. Soc. C. E., thanking the Association for its hospitality to him as its guest on January 23d, 1918.

The proposed change in the Constitution of the Society was discussed, and President Ockerson urged all members to vote.

Mr. Clinton H. Fisk addressed the meeting on the programme of the Quartermaster's Department in Utilizing the Civilian Engineer.

Mr. A. P. Greensfelder read a report of the Building Industries Committee of St. Louis on the Building Industry and the War.

On motion, duly seconded, the Association endorsed the Report of the Building Industries Committee of St. Louis, as submitted to the St. Louis Chamber of Commerce on February 25, 1918.

Adjourned.

San Diego Association, Organized 1915.

N. B. Kellogg, President; J. R. Comly, Secretary-Treasurer, 4105 Falcon Street, San Diego, Cal.

Seattle Association, Organized 1913.

A. S. Downey, President; Phil. A. Franklin, Secretary, Care, City Engineer's Office, County-City Building, Seattle, Wash.

The regular monthly meetings and luncheons of the Association are held at the Frye Hotel, 3d Avenue and Yesler Way, at 12.15 P. M., on the last Monday of each month. All members, in any grade, of the American Society of Civil Engineers are cordially invited to attend the meetings when in the vicinity.

Southern California Association, Organized 1914.

H. Hawgood, President; H. W. Dennis, Secretary, 329 San Fernando Building, Los Angeles, Cal.

The Southern California Association of Members of the American Society of Civil Engineers (Los Angeles, Cal.) holds regular bimonthly meetings with banquet, at Hotel Clark, on the second Wednesday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M. every Wednesday, and the place of meeting may be ascertained from the Secretary.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in Los Angeles, and any such member will be gladly welcomed as a guest at any of the meetings or luncheons.

Spokane Association, Organized 1914.

J. C. Ralston, President; B. J. Garnett, Secretary, City Hall, Spokane, Wash.

The regular meetings of the Association are held on the second Friday of each month, except July and August. The hour and place

of meeting are not fixed, but this information will be furnished on application to the Secretary.

Visiting members are invited to attend the meetings and luncheons.

Texas Association, Organized 1913.

J. M. Howe, President; J. F. Witt, Secretary, Dallas, Tex.

Utah Association, Organized 1916.

George L. Swendsen, President; H. S. Kleinschmidt, Secretary-Treasurer, 306 Dooly Building, Salt Lake City, Utah.

The Annual Meeting of the Association is held on the first Wednesday in April. The time of other meetings is not fixed, but this information will be furnished on application to the Secretary.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms, and at all meetings:

American Institute of Electrical Engineers, 25 West Thirty-ninth Street, New York City.

American Institute of Mining Engineers, 25 West Thirty-ninth Street, New York City.

American Society of Mechanical Engineers, 25 West Thirty-ninth Street, New York City.

Assoçiacão dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 176 Mansfield Street, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, Public Library, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Detroit Engineering Society, Detroit Board of Commerce Building, Detroit, Mich.

Engineering Association of Nashville, Commercial Club Building, Nashville, Tenn.

Engineering Association of New South Wales, 5 Elizabeth Street, Sydney, New South Wales, Australia.

Engineering Societies Club of Hawaii, E. F. Cykler, Secretary, Honolulu, Hawaii.

Engineers and Architects Club of Louisville, 1412 Starks Building, Louisville, Ky.

Engineers' Club of Baltimore, 6 West Eager Street, Baltimore, Md.

Engineers' Club of Kansas City, Robert S. Beard, Secretary, Third Floor, City Hall, Kansas City, Mo.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Club of Trenton, Trent Theatre Building, 12 North Warren Street, Trenton, N. J.

Engineers' Society of Northeastern Pennsylvania, 415 Washington Avenue, Scranton, Pa.

Engineers' Society of Pennsylvania, 31 South Front Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 568 Union Arcade Building, Pittsburgh, Pa.

Florida Engineering Society, J. R. Benton, Secretary, Gainesville, Fla.

Institute of Marine Engineers, The Minories, Tower Hill, London, E., England.

Institution of Civil Engineers, Great George Street, Westminster, S. W., London, England.

Institution of Engineers of the River Plate, Calle 25 de Mayo 195, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, State Museum Building, Chartres and St. Ann Streets, New Orleans, La.

Memphis Engineers' Club, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Montana Society of Engineers, Butte, Mont.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Oregon Society of Civil Engineers, Portland, Ore.

Pacific Northwest Society of Engineers, 803 Central Building, Seattle, Wash.

Rochester Engineering Society, Rochester, N. Y.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Societe des Ingenieurs Civils de France, 19 rue Blanche, Paris, France.

Society of Engineers, 17 Victoria Street, Westminster, S. W., London, England.

Southwestern Society of Engineers, C. E. Barglebaugh, Secretary, 703 First National Bank Building, El Paso, Tex.

Svenska Teknologforeningen, Brunkebergstorg 18, Stockholm, Sweden.

Tekniske Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Vermont Society of Engineers, George A. Reed, Secretary, Montpelier, Vt.

Western Society of Engineers, 1735 Monadnock Block, Chicago, Ill.

ACCESSIONS TO THE UNITED ENGINEERING SOCIETY LIBRARY

(From February 1st to March 1st, 1918)

DONATIONS*

The statements made in these notices are taken from the books themselves, and this Society is not responsible for them.

CENTRAL STATIONS.

By Terrell Croft. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 10 + 332 pp., 306 illus., 8 x 6 in., cloth. $2.50.

A description of current practice in the generation, transmission, and distribution of electrical energy, in a form adapted to readers of modest mathematical attainments. Contents: Distribution-System Nomenclature; Distribution Loss and Distribution Loss Factors; Maximum Demand and Demand Factors; Diversity and Diversity Factors; Load Factor, Plant Factor, and Connected-Load Factor; Load Graphs and Their Significance; General Principles of Current Design; Calculation and Design of Direct-Current Circuits; Calculation and Design of Alternating-Current Circuits; Transmission and Distribution of Electrical Energy; Lighting Protection Apparatus; Automatic Voltage Regulators; Switchboards and Switchgear; Characteristics of Electric Generating Stations; Adaptability of Steam Internal Combustion Engine and Hydraulic Prime Movers; Steam Electrical-Energy-Generating Stations; Internal Combustion Engine Stations; Hydro-Electric Stations.

CONTINUOUS-CURRENT MOTORS AND CONTROL APPARATUS:

A Practical Book for all Classes of Technical Readers. By W. Perren Maycock. N. Y. and Lond., Whittaker & Co., 1917. 16 + 331 pp., 150 illus., 8 x 5 in., cloth. $2.25. (Gift of The Macmillan Co.)

Discusses the kinds of apparatus and motors in use, their connections, actions, testing and applications. Does not treat of design nor manufacture. Intended for those interested in installing and operating continuous-current motors.

POWER WIRING DIAGRAMS:

A Handbook of Connection Diagrams of Control and Protective Systems for Industrial Plants. By A. T. Dover. N. Y. and Lond., Whittaker & Co., 1917. 15 + 208 pp., 254 illus., 7 x 4 in., cloth. $2.25. (Gift of The Macmillan Co.)

A pocket-book of detail diagrams, drawn to represent the actual control apparatus to which they refer, instead of being merely ideal. The apparatus described is that used in Great Britain.

THE ALDRICH MARINE DIRECTORY:

Containing (A) List of Concerns Which Build and Repair Vessels; (B) List of Steamship, Steamboat, and Other Vessel Owners Using the American Flag. N. Y., Aldrich Publishing Co., 1918. 220 pp., 8 x 4 in., flexible cloth. $5.00.

These lists are arranged geographically. The location, officers, kind, and maximum size of vessels built are given for each shipyard. The list of owners gives the location, officers, and the names, tonnage, and service of the vessels.

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* Unless otherwise specified, books in this list have been donated by the publishers.

KINEMATICS OF MACHINERY:

A Text-Book on Mechanisms and Their Properties with Many Practical Applications for Engineers and for Students in Technical Schools. By Arthur Warner Klein. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 15 + 227 pp., 118 illus., 7 diagrams, 9 x 6 in., cloth. $2.50.

This treatise occupies itself with the equivalence displacement, velocities, and accelerations of mechanisms and gives the necessary preliminaries in the way of auxiliary constructions and theorems with applications to many practical problems. These are solved by relatively simple graphical methods.

FINDING AND STOPPING WASTE IN MODERN BOILER ROOMS:

Vol. 2, A Reference Manual to Aid the Owner, Manager, and Boiler-Room Operator in Securing and Maintaining Plant Economy. Phila., Harrison Safety Boiler Works, 1918. 274 pp., 120 illus., 7 x 5 in., linen. $1.00.

This work is a handbook of practical information, compiled from the best authorities available, and is a convenient reference manual on boiler-room practice. Contents: Fuels; Combustion; Heat Absorption; Boiler Efficiency and Boiler Testing; Boiler Plant Proportioning and Management; Cochrane Meters.

MEASUREMENT OF GAS BY ORIFICE METER.

By Henry P. Westcott. Erie, Metric Metal Works, 1918. 408 pp., 35 illus., tab., 8 x 5 in., cloth. $3.50.

Although there have been many circulars and papers written on the subject of the orifice meter and orifice measurement, no attempt has been made to collect and preserve these data in book form, and it is the author's intention to fill this need, and, in addition, to add a full set of pressure extensions so necessary in figuring gauge charts.

AUTOMOBILE STARTING, LIGHTING, AND IGNITION:

A Complete Exposition Explaining all Forms of Electrical Ignition Systems Used with Internal Combustion Engines of all Types, also Including a Comprehensive Series of Instructions Pertaining to Starting and Lighting Systems of Automobiles. By Victor W. Pagé. 4th ed., rev. N. Y., The Norman W. Henley Publishing Co., 1918. 519 pp., 298 illus., 8 x 5 in., flexible cloth. $1.50.

Intended for owners, operators, and mechanics. The descriptions are non-mathematical but detailed. A chapter is devoted to the miscellaneous electrical devices used on automobiles.

MODEL AEROPLANES AND THEIR ENGINES:

A Practical Book for Beginners. By George A. Cavanagh. Drawings by Harry G. Schultz, with an Introduction by Henry Woodhouse. N. Y., Moffat Yard & Company, 1917. 152 pp., 20 illus., 19 pl., 8 x 5 in., cloth. $1.00.

This work includes both models launched by hand and those driven by compressed air, gasoline, or steam. Detailed directions for the construction of several types are given.

AVIATION ENGINES:

Design, Construction, Operation and Repair; A Complete, Practical Treatise Outlining Clearly the Elements of Internal Combustion Engineering with Special Reference to the Design, Construction, Operation, and Repair of Airplane Power Plants; also the Auxiliary Engine Systems, such as Lubrication, Carburetion, Ignition, and Cooling. It Includes Complete Instructions for Engine Repairing and Systematic Location of Troubles, Tool Equipment, and Use of Tools, also Outlines the Latest Mechanical Processes. By Victor W. Pagé. N. Y., The Norman W. Henley Publishing Co., 1918. 589 pp., 253 illus., 9 x 6 in., cloth. $3.00.

A text-book intended for instruction purposes, especially for students preparing for service as aviators or aviation mechanics in the Aviation Section of the Signal Corps. The author is Assistant Engineering Officer in the Signal Corps Aviation School.

TESTING FOR THE FLOTATION PROCESS.

By A. W. Fahrenwald. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 173 pp., 34 illus., 7 x 4 in., leather. $1.50.

Written to present the various theories of flotation and to furnish the information necessary to conduct intelligent tests for the flotation process. Contents: Concentration by Flotation; Classification of the Flotation Process; The Theory of Flotation; The Flotation of Oxidized Ores; Oil and Other Reagents in Flotation; Tests; Cost of Flotation; Formulas and Tables.

NOTES ON MILITARY EXPLOSIVES.

By Erasmus Weaver. 4th ed., rev. and enl. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 382 pp., 9 x 6 in., cloth. $3.25.

The present edition of this book has been thoroughly revised and brought up to date by including the changes in the manufacture, use, storage, and transportation of military explosives which have been developed between 1912 and 1916. Contents: Principles of Chemistry; Substances Used in the Manufacture of Explosives; General Remarks on Explosives; Progressive Explosives; Detonating Explosives; Exploders; Service Tests of Explosives; Storage of Explosives; Handling High Explosives; Demolitions.

A SHORT HISTORY OF SCIENCE.

By W. T. Sedgwick and H. W. Tyler. N. Y., The Macmillan Company, 1917. 15 + 474 pp., 9 x 6 in., cloth. $2.50.

The present work aims to furnish the student and the general reader with a concise account of the origin of that scientific knowledge and that scientific method which have come to have so important a share in shaping the conditions and directing the activities of human life. It is based on a lecture course given by the authors to undergraduate classes in the Massachusetts Institute of Technology for the purpose of furnishing a broad general perspective of the evolution of science, and of the relations of the sciences to each other and to the general progress of civilization.

OPTIC PROJECTION:

Principles, Installation, and Use of the Magic Lantern, Projection Microscope, Reflecting Lantern, Moving Picture Machine. By Simon Henry Gage and Henry Phelps Gage. Ithaca, Comstock Publishing Co., 1914. 731 pp., 413 illus., 9 x 6 in., cloth. $3.00.

The aims of the authors have been to explain the underlying principles of optic projection and to give such simple, explicit directions that any intelligent person can succeed in all the fields of the art. Contains appendices giving a brief historical summary, list of manufactures, and a bibliography.

DESCRIPTIVE GEOMETRY.

By Ervin Kenison and Harry Cyrus Bradley. N. Y., The Macmillan Company, 1917. 10 + 287 pp., 332 illus., 8 x 5 in., cloth. $2.00.

A college text-book, representing the instruction given at the Massachusetts Institute of Technology. The point of view is that of the draftsman, and the text is designed to train him to see clearly the conditions of a drawing in space.

THE PRINCIPLES OF ECONOMIC GEOLOGY.

By William Harvey Emmons. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1918. 18 + 606 pp., 210 illus., 9 x 6 in., cloth. $4.00.

An attempt to present as briefly as practicable to advanced students of geology, a perspective of the science of metalliferous and non-metalliferous deposits, excluding mineral fuels. Numerous bibliographies on special topics are included.

STATISTICS.

By William B. Bailey and John Cummings. Chic., A. C. McClurg & Co., 1917. 153 pp., 7 x 4 in., cloth. 60 cents.

An elementary work for those who need an acquaintance with the fundamentals of the subject. Mathematical formulas have been avoided when possible. A bibliography of works in English is included. Contents: Importance of Statistics; The Field of Study; Gathering the Raw Material; Editing Schedules; Tabulation; Ratios; Averages; Graphic Representation; Correlation; Bibliography.

ENZYMES AND THEIR APPLICATIONS.

By Jean Effront. English Translation by Samuel C. Prescott. N. Y., John Wiley & Sons; Lond., Chapman & Hall, Ltd. (copyright 1902). 11 + 332 pp., 9 x 6 in., cloth. $3.00.

Treats of the enzymes of carbohydrates and the oxidases. Gives particular attention to the theoretical questions involved in their action, but also discusses their industrial applications. Bibliographies are appended to each chapter.

DRYING CLAY WARES.

By Ellis Lovejoy. Indianapolis, T. A. Randall & Co. (copyright 1916). 166 pp., 86 illus., 9 x 6 in., cloth. $2.00.

As the existing treatises on heating, ventilation, and drying do not contain adequate data applicable to the drying of clay wares, the author has selected the existing information of use in this work, and has modified it to suit the conditions met. These treatises appeared first as a series of articles in the *Clay-Worker*.

FRENCH FORESTS AND FORESTRY:

Tunisia, Algeria, Corsica; with a Translation of the Algerian Code of 1903. By Theodore S. Woolsey, Jr. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 15 + 238 pp., 20 illus., 9 x 6 in., cloth. $2.50.

This work embodies the results of a study of the more important phases of forest practice in the French Colonies mentioned, with the aim of presenting the essentials of methods which may be applied directly in the United States. Generalizations and comparisons between French and American methods have been largely omitted; the idea has been, instead, to describe the methods used and the results obtained in countries where many of the conditions approximate those met by American foresters.

ELEMENTS OF PLUMBING.

By Samuel Edward Dibble. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1918. 170 pp., 83 illus., 7 x 5 in., cloth. $1.50.

This is a text-book for beginners, which describes in minute detail the various methods used by plumbers, the tools, and the standard forms of fixtures. Water supply to buildings, the removal of waste waters, and gas fitting are considered, and plumbing codes are given.

DISTRICT HEATING:

A Brief Exposition of the Development of District Heating and Its Position among Public Utilities. By S. Morgan Bushnell and Fred. B. Orr. N. Y., Heating and Ventilating Magazine Co., 1915. 290 pp., 82 illus., 1 por., 9 x 6 in., cloth. $3.00.

It has been the endeavor of the authors to take up, in a brief manner, the development of the art of District Heating, as far as possible, from a non-technical standpoint, in order that those who have not had experience with this subject might obtain a general knowledge of it and its relation to other public utilities. As a rule the discussion of the more involved technical points has been avoided, the reader being referred to standard text-books and other engineering literature which take up these subjects in detail. The object of the book is not only to impart a general knowledge of District Heating to those who wish to study the subject, but also to promote the interests of District Heating companies. For this purpose various points on economical operation are suggested, as illustrated in the methods practiced by companies which have made a success in this line of work. Comparative data are presented indicating the prices that can reasonably be charged for heating service. Contents: Origin and Development of District Heating; Selling of Heat; Heat Distribution Systems; Metering; District-Heating Stations; Methods of Estimating Heating Requirements in Buildings; Estimating Miscellaneous Steam Requirements in Buildings; Relation Between Heat Load and Electric Load in Buildings; The Use of Heating Data in Making Estimates on the Comparative Costs of Isolated Plant and Central-Station Service; Relation Between Central-Station Heating and Central-Station Lighting and Power.

METER RATES FOR WATER WORKS.

By Allen Hazen. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1918. 217 pp., 21 illus., 9 x 6 in., cloth. $2.25.

This book deals with the problem of distributing the burden of supporting a water-works system among those who use the water, in a just and equitable manner. It also deals with the technic of handling statistics that must be used, of making the required computations, and of estimating the revenue that will be produced by a given set of rates. The volume is based on the author's service as Chairman of the Committee on Water Rates of the New England Water Works Association and his experience in establishing water rates in various water-works systems.

ROLL OF HONOR

A List of Members of the Society Who are Serving in the Army or Navy of the United States or Any of Its Allies.*

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* This list is made up from replies to a circular forwarded to members of the Society, and others, and is probably neither accurate nor complete. It is requested that the attention of the Secretary be called to any omissions or inaccuracies in order that they may be corrected in subsequent lists.

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Taylor, Wyllys H. Capt., Engr. R. C., 306th Engrs., N. A. (81st Div.), Camp Jackson, Columbia, S. C.

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Young, Samuel M. Capt., Engr. R. C., Camp Lee, Petersburg, Va.

Zinn, George A. Col., Corps of Engrs., U. S. A., 321 Custom House, Portland, Ore.

MEMBERSHIP

(From February 8th to March 7th, 1918)

ADDITIONS

MEMBERS		Date of Membership.
Bannon, Anthony Francis, Jr. Cons. Engr., Bradford, Pa.		Sept. 11, 1917
Black, Dudley Frank. Capt., Engrs., U. S. R., Camp Travis, Tex.; 1338 Milton Ave., Hollywood, Cal.	Assoc. M. M.	April 2, 1912 Jan. 14, 1918
Edmondstone, George Stovall. Asst. Engr. in Chg. of Constr., Comm. of Public Docks, 1289 Rodney Ave., Portland, Ore.		Nov. 27, 1917
Shannon, William Day. Gen. Supt., Stone & Webster, P. O. Box 297, Youngstown, Ohio	Assoc. M. M.	Dec. 5, 1911 Jan. 14, 1918
Waddell, Needham Everett. Cons. Engr. (Waddell & Son), 800 Graphic Arts Bldg., Kansas City, Mo.	Jun. Assoc. M. M.	Sept. 1, 1908 May 7, 1913 Jan. 14, 1918

ASSOCIATE MEMBERS		
Bennett, Fred. P. O. Box 487, Little Rock, Ark.		Oct. 9, 1917
Butler, Arthur Gray. Supt., Alfred Struck Co., 11 Eastover Court, Louisville, Ky.	Jun. Assoc. M.	June 23, 1916 Oct 9, 1917
Carter, Clarence Reed. Div. Mgr., Texas Gas & Elec. Co., Center, Tex.	Jun. Assoc. M.	Feb. 4, 1914 Jan. 14, 1918
Gellert, Nathan Henry. 308 Widener Bldg., Philadelphia, Pa.		Oct. 9, 1917
Hirzel, Alfred Sparks. Capt., 1st Delaware Inf., Camp Dix, N. J. (Res., 1300 Shallcross Ave., Wilmington, Del.)	Jun. Assoc. M.	Sept. 3, 1913 Nov. 27, 1917
Jerrard, Leigh Patterson. 2d Lieut., Headquarters, 67th Artillery Brigade, Am. Exp. Forces, France (Res., 215 South Broom St., Madison, Wis.)	Jun. Assoc. M.	Oct. 5, 1909 Oct. 9, 1917
Johnson, John Monroe. Maj., 1st Bn., 117th Engrs., Headquarters, Am. Exp. Forces, France		Nov. 27, 1917
Johnstone, Leslie Ingalls. Asst. Prof. of Civ. Eng., Univ. of Manitoba, 177 Oak St., Winnipeg, Man., Canada		Jan. 14, 1918
Lansdale, John. Capt., Engrs., U. S. R. Military Post Office No. 701, Am. Exp. Forces, France		Sept. 11, 1917
Larsen, Peter Magnus. Station F, Kansas City, Mo.		Jan. 14, 1918
Lawrence, Frank Elmaker. Lieut., 17th Engrs. (Ry.), Am. Exp. Forces, France; Care, C. K. Lawrence, 415 West 36th St., Savannah, Ga.		Nov. 27, 1917

ASSOCIATE MEMBERS (*Continued*)

		Date of Membership.
Malloy, John Michael. Lieut., 342d F. A., Camp Funston, Kans.; 1704 Marquette St., Davenport, Iowa		Nov. 27, 1917
Marston, Frank Alwyn. Designing Engr., Metcalf & Eddy, 20 Phillips St., Wollaston, Mass.	Jun. Assoc. M.	Mar. 1, 1910 Sept. 11, 1917
May, Donald Curtis. Office Engr., Gardner S. Williams, Cornwell Bldg., Ann Arbor, Mich.	Jun. Assoc. M.	May 6, 1914 Jan. 14, 1918
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Plank, David Harlan. 1st Lieut., Engrs. U. S. R., Co. B. 310th Engrs., Camp Custer, Battle Creek, Mich.		Sept. 11, 1917
Smith, Alexander Crawford, Jr. 1st Lieut., Engrs., U. S. R.; 1009 North Calvert St., Baltimore, Md.	Jun. Assoc. M.	April 30, 1912 Jan. 14, 1918
Smith, Earl Audie. 1st Lieut., Engrs. U. S. R., Fort Leavenworth, Kans.	Jun. Assoc. M.	June 24, 1914 Sept. 11, 1917
Weiner, Peter. 797 Crotona Park, North, New York City.		Sept. 11, 1917
Williams, Howard Stephen. County Engr., Cass County, County Court House, Atlantic, Iowa		Sept. 11, 1917
Wyckoff, Maurice Mayer. The New Packer House, Perth Amboy, N. J.		Jan. 14, 1918
Yeo, William Albert. Engr. in Chg., Nicaragua Development Corporation, Pearl Lagoon, Nicaragua	Jun. Assoc. M.	Oct. 1, 1907 Nov. 27, 1917

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JUNIORS

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Ball, Edwin Leo. Box 285, Pineville, La.	Jan. 14, 1918
Hyde, Richard Lewis. 2d Lieut., 10th U. S. Engrs., Am. Exp. Forces, France; 425 West 162d St., New York City	Sept. 11, 1917
Logan, Vernon Lemley. 1st Class Sergeant, Co. A, 110th Engrs.; Co. 5, E. R. O. T. C., Camp Lee, Petersburg, Va.	Nov. 27, 1917
Matthews, Albert Clark, Jr. Transitman, Valuation Dept., B. & O. Ry., Box 271, Baltimore, Md.	Oct. 9, 1917
Ranney, Alfred Gardner. Capt., Battery A, 65th Artillery, C. A. C.; Care, Bartlett & Ranney, Inc., 108 East Crockett St., San Antonio, Tex.	Sept 11, 1917

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JUNIORS (*Continued*)

Bauer, John, Jr. Min. Engr., Hanna Ore Min. Co., Crystal Falls, Mich.

Breymann, John Bernard, Jr. Officers' Training Camp, Coast Artillery Corps, 4th Training Co., Fort Monroe, Va.

Collins, Merton Clyde. 1st Lieut., Engrs., U. S. R. (*Unassigned*); Dist. Engr., Cotabato Province, Mindanao, Philippine Islands.

Connolly, Allen Howard. Aviation Section, Signal Corps, Columbus, Ohio; Address, Basking Ridge, N. J.

Cotter, Carl Henry. Asst. Civ. Engr., U. S. N., Navy Yard, Washington, D. C.

Flagg, Herbert Judson. Capt., C. A. N. G., Fort Flagler, Wash.

Getty, Lorenzo Todd. 1st Lieut., A. S., S. C., U. S. A., 75th Aero Constr. Squadron, Am. Exp. Forces, France; 359 West 26th St., New York City.

Gray, Earle Pierce. 1st Lieut., Engrs., U. S. R., 16th Engrs. (Ry.), U. S. A., Am. Exp. Forces, France; 1129 White St., Ann Arbor, Mich.

Jaenicke, William Hugo. Care, 319th Engrs., Camp Fremont, Cal.

Keith, Gerald Marcy. Lieut., Engrs., U. S. R., Co. B, 116th Engrs., Am. Exp. Forces, France.

Larson, Louis J. Laboratory Asst. on Military Research, Bureau of Standards, Washington, D. C. (Res., 3739 Jocelyn St., Chevy Chase, Md.).

McGee, Harold Gilbert. Care, C. H. McGee, 1487 North Los Robles Ave., Pasadena, Cal.

Reynolds, Ralph Whitney. 1st Lieut., Engrs., U. S. R., Engr. Replacement Troops, Vancouver Barracks, Vancouver, Wash.; 270 South Harvard Boulevard, Los Angeles, Cal.

Rimbault, Emile Leonard, Jr. Chf., Structural Dept., E. F. Terry Mfg. Co., Grand Central Terminal (Res., 39 Seaman Ave.), New York City.

Stanley, William Edward. 1st Lieut., Engrs. U. S. R., Co. B, 101st Engrs., Am. Exp. Forces, France; Care, J. W. Stanley, Burrton, Kans.

Steinberg, Max. 1st Lieut., U. S. R.; Junior Hydrographic and Geodetic Engr., U. S. Coast and Geodetic Survey, Washington, D. C.

Street, John Zadok. Private, Specialist Detachment, 26th Engrs.; Care, Thomas A. Gilkey, Mercantile Bldg., New Castle, Pa.

Tilton, George Albert, Jr. San Luis Obispo, Cal.

Tracy, Clarence Curtis. Capt., C. A. R. C., Fort Terry, N. Y.

Van Ness, Russell Alger. Lieut., Engrs., U. S. R., Co. 2, E. R. O. T. C., Camp Lee, Petersburg, Va.

Veltfort, Theodore Ernst. Progress Engr., Am. International Shipbuilding Corporation, 140 North Broad St., Philadelphia (Res., H 14 Third Ave., Presser Park, Yeadon), Pa.

Wagner, John, Jr. 1st Lieut., Cavalry, U. S. R., First Corps School, Army P. O. 703. France.

Whalen, William Edward. Asst. to Gen. Supt. of Bldg. Constr., Willys Overland Co. (Res., 2106 Putnam St.), Toledo, Ohio.

Whitmore, Harold Cushing. Constr. Engr., Stone & Webster (Res., 91 Baker St.), Lynn, Mass.

JUNIORS (*Continued*)

WONG, JICK GAM. Res. Engr., Section 10, Hankow-Ichang Ry., Yangkiahung, Hupeh Province, China.

WOOLWORTH, WENDELL HOWARD. Capt., U. S. A., Headquarters, 2d Brigade, 1st Div., Am. Exp. Forces, France.

YEREANCE, ALEXANDER WOODWARD. 2d Lieut., 305th Engrs., N. A.; 418 Centre St., South Orange, N. J.

RESIGNATIONS

JUNIORS	Date of Resignation
DANA, FOREST CHARLES	Dec. 31, 1917

DEATHS

GAY, CHARLES WEBSTER. Elected Member, May 6th, 1891; died February 1st, 1918.

SONNE, OTTO. Elected Member, September 7th, 1887; died November 13th, 1917.

VORCE, CLARENCE BROWNING. Elected Junior, April 30th, 1895; Associate Member, October 7th, 1896; Member, May 2d, 1890; died February 4th, 1918.

WATERHOUSE, JOHN. Elected Member, October 4th, 1899; died February 20th, 1918.

WRIGHT, AUGUSTINE WASHINGTON. Elected Member, May 5th, 1886; died February 3d, 1918.

Total Membership of the Society, March 7th, 1918,
8 629.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(January 1st to February 28th, 1918)

NOTE.—*This list is published for the purpose of placing before the members of this Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(2) *Proceedings,* Engrs. Club of Phila., Philadelphia, Pa.
(3) *Journal,* Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal,* Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Transactions,* Can. Soc. C. E., Montreal, Que., Canada.
(6) *Journal,* Am. Inst. of Archts., Washington, D. C., 50c.
(7) *Gesundheits Ingenieur,* München, Germany.
(8) *Stevens Indicator,* Hoboken, N. J., 50c.
(9) *Industrial Management,* New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, 432 Fourth Ave., New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News-Record,* New York City, 15c.
(15) *Railway Age,* New York City, 15c.
(16) *Engineering and Mining Journal,* New York City, 15c.
(17) *Electric Railway Journal,* New York City, 10c.
(18) *Railway Review,* Chicago, Ill., 15c.
(19) *Scientific American Supplement,* New York City, 10c.
(20) *Iron Age,* New York City, 20c.
(21) *Railway Engineer,* London, England, 1s. 2d.
(22) *Iron and Coal Trades Review,* London, England, 6d.
(23) *Railway Gazette,* London, England, 6d.
(24) *American Gas Engineering Journal,* New York City, 10c.
(25) *Railway Mechanical Engineer,* New York City, 20c.
(26) *Electrical Review,* London, England, 4d.
(27) *Electrical World,* New York City, 10c.
(28) *Journal,* New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal,* Royal Society of Arts, London, England, 6d.
(30) *Annales des Travaux Publics de Belgique,* Brussels, Belgium, 4 fr.
(31) *Annales* de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand, Brussels, Belgium, 4 fr.
(32) *Mémoires et Compte Rendu des Travaux,* Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil,* Paris, France, 1 fr.
(34) *Portefeuille Economiques des Machines,* Paris, France.
(35) *Nouvelles Annales de la Construction,* Paris, France.
(36) *Cornell Civil Engineer,* Ithaca, N. Y.
(37) *Revue de Mécanique,* Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways,* Paris, France.
(39) *Technisches Gemeindeblatt,* Berlin, Germany, 0, 70m.
(40) *Zentralblatt der Bauverwaltung,* Berlin, Germany, 60 pfg.
(41) *Electrotechnische Zeitschrift,* Berlin, Germany.
(42) *Proceedings,* Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées,* Paris, France.
(44) *Journal,* Military Service Institution, Governors Island, New York Harbor, 50c.
(45) *Coal Age,* New York City, 10c.
(46) *Scientific American,* New York City, 15c.
(47) *Mechanical Engineer,* Manchester, England, 3d.
(48) *Zeitschrift,* Verein Deutscher Ingenieure, Berlin, Germany, 1, 60m.
(49) *Zeitschrift für Bauwesen,* Berlin, Germany.
(50) *Stahl und Eisen,* Düsseldorf, Germany.
(51) *Deutsche Bauzeitung,* Berlin, Germany.
(52) *Rigasche Industrie-Zeitung,* Riga, Russia, 25 kop.
(53) *Zeitschrift,* Oesterreichischer Ingenieur und Architekten Vereines, Vienna, Austria, 70h.
(54) *Transactions,* Am. Soc. C. E., New York City, $12.
(55) *Transactions,* Am. Soc. M. E., New York City, $10.

(56) *Transactions,* Am. Inst. Min. Engrs., New York City, $6.
(57) *Colliery Guardian,* London, England, 5d.
(58) *Proceedings,* Engrs.' Soc. W. Pa., 2511 Oliver Bldg., Pittsburgh, Pa., 50c.
(59) *Proceedings,* Am. Water-Works Assoc., Troy, N. Y.
(60) *Municipal Engineering,* Indianapolis, Ind., 25c.
(61) *Proceedings,* Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Drop Forger,* Thaw Bldg., Pittsburgh, Pa., 10c.
(63) *Minutes of Proceedings,* Inst. C. E., London, England.
(64) *Power,* New York City, 5c.
(65) *Official Proceedings,* New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Gas Journal,* London, England, 6d.
(67) *Cement and Engineering News,* Chicago, Ill., 25c.
(69) *Der Eisenbau,* Leipzig, Germany.
(71) *Journal,* Iron and Steel Inst., London, England.
(71*a*) *Carnegie Scholarship Memoirs,* Iron and Steel Inst., London, England.
(72) *American Machinist,* New York City, 15c.
(73) *Electrician,* London, England, 18c.
(74) *Transactions,* Inst. of Min. and Metal., London, England.
(75) *Proceedings,* Inst. of Mech. Engrs., London, England.
(76) *Brick,* Chicago, Ill., 20c.
(77) *Journal,* Inst. Elec. Engrs., London, England, 5s.
(78) *Beton und Eisen,* Vienna, Austria, 1, 50m.
(79) *Forscherarbeiten,* Vienna, Austria.
(80) *Tonindustrie Zeitung,* Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen,* Wiesbaden, Germany.
(83) *Gas Age,* New York City, 15c.
(84) *Le Ciment,* Paris, France.
(85) *Proceedings,* Am. Ry. Eng. Assoc., Chicago, Ill.
(86) *Engineering and Contracting,* Chicago, Ill., 10c.
(87) *Railway Engineering and Maintenance of Way,* Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.
(89) *Proceedings,* Am. Soc. for Testing Materials, Philadelphia, Pa., $5.
(90) *Transactions,* Inst. of Naval Archts., London, England.
(91) *Transactions,* Soc. Naval Archts. and Marine Engrs., New York City.
(92) *Bulletin,* Soc. d'Encouragement pour l'Industrie Nationale, Paris, France.
(93) *Revue de Métallurgie,* Paris, France, 4 fr. 50.
(95) *International Marine Engineering,* New York City, 20c.
(96) *Canadian Engineer,* Toronto, Ont., Canada, 10c.
(98) *Journal,* Engrs. Soc. Pa., Harrisburg, Pa., 30c.
(99) *Proceedings,* Am. Soc. of Municipal Improvements, New York City, $2.
(100) *Professional Memoirs,* Corps of Engrs., U. S. A., Washington, D. C., 50c.
(101) *Metal Worker,* New York City, 10c.
(102) *Organ für die Fortschritte des Eisenbahnwesens,* Wiesbaden, Germany.
(103) *Mining and Scientific Press,* San Francisco, Cal., 10c.
(104) *The Surveyor and Municipal and County Engineer,* London, England, 6d.
(105) *Metallurgical and Chemical Engineering,* New York City, 25c.
(106) *Transactions,* Inst. of Min. Engrs., London, England, 6s.
(107) *Schweizerische Bauzeitung,* Zürich, Switzerland.
(108) *Southern Machinery,* Atlanta, Ga., 10c.
(109) *Journal,* Boston Soc. C. E., Boston, Mass., 50c.
(110) *Journal,* Am. Concrete Inst., Philadelphia, Pa., 50c.
(111) *Journal of Electricity, Power and Gas,* San Francisco, Cal., 25c.
(112) *Internationale Zeitschrift für Wasser-Versorgung,* Leipzig, Germany.
(113) *Proceedings,* Am. Wood Preservers' Assoc., Baltimore, Md.
(114) *Journal,* Institution of Municipal and County Engrs., London, England, 1s. 6d.
(115) *Journal,* Engrs.' Club of St. Louis, St. Louis, Mo., 35c.
(116) *Blast Furnace and Steel Plant,* Pittsburgh, Pa., 15c.

LIST OF ARTICLES

Bridges.

Mt. Pleasant Road Bridge, Toronto.* J. S. Burgoyne. (96) Jan. 10.
Problems and General Methods of Erecting the Sciotoville Bridge.* Clyde B. Pyle. (13) Jan. 10.
Turning Back Abutment Wing Walls Saves Material.* Charles K. Mohler. (13) Jan. 24.
The Sciotoville Bridge.* Frank W. Skinner. (11) Jan. 25.
Expansion Joints and Traction Trusses, Quebec Bridge.* Archibald John Meyers. (96) Feb. 7.
New Pennsylvania Railroad Bridge at Manayunk, Pa.* Albert M. Wolf. (18) Feb. 9.
Bridge Work in Guatemala Torrent Used Armored Tower. (13) Feb. 14.

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* Illustrated.

Bridges—(Continued).

Illinois Central Bascule Bridge is Hand Operated.* (13) Feb. 14.
Shifting a 4 000-Ton Bridge on Freight Car Trucks.* (15) Feb. 15.
Concrete-Arch Railway Bridge Costs Less Than Steel.* (13) Feb. 21.
Le Pont Basculant Système Scherzer de Keadby (Angleterre).* P. Calfas. (33) Jan. 19.
Die Fertigstellung der St. Lawrence-Brücke bei Quebec.* A. Rohn. (107) Jan. 26.

Electrical.

The Problem of Artificial Lighting.* C. E. Clewell. (9) Jan.
The Technical Story of the Frequencies. B. G. Lamme. (42) Jan.
Electric Clock at Agnews Hospital.* L. A. Gain. (111) Jan. 1.
Application of Large Hydro-Electric Units. Arnold Pfau. (111) Jan. 1.
Electrical Inspection. E. F. Dunlap. (Abstract of a paper read before the Convention of Oregon Contractors and Dealers.) (111) Jan. 1.
National Electric Code—Marine Work. (111) Jan. 1.
Condensers for Power Circuits.* (73) Jan. 4.
Electric Power Supply at Buenos Aires.* (11) Jan. 4.
Joint Boxes and Terminals for Split Conductor Cables.* (26) Jan. 4.
Adopting Existing Lines to Increased Loads.* E. B. Hook, Jr. (27) Jan. 5.
Electrical Interconnection to Conserve Fuel.* (27) Jan. 5.
Increasing Output Without Enlarging Equipment.* Joseph T. Foster. (27) Jan. 5.
Shipbuilding Expedited by Electric Service.* David Elwell. (27) Jan. 5.
Methods of Drying Out Flooded Power Plant Equipment.* Norman L. Rea. (64) Jan. 8.
Operation and Maintenance of Elevators-Winding-Drum Machines.* R. H. Whitehead. (64) Jan. 8.
The Care of Commutators of Direct-Current Machinery.* L. Fokes. (57) Jan. 11.
Some Points of Interest to Northumberland and Durham Colliery Engineers. A. C. Nelson. (Abstract of paper read before the North of England Branch of the Assoc. of Min. Elec. Engrs.) (73) Jan. 11.
Cyclic Fluctuations in Rate of Lamp Renewal. M. D. Cooper. (27) Jan. 12.
Electric Railway Power at Montreal.* (17) Jan. 12.
Design of Rotor Cores for Electrical Machines. William Knight. (27) Jan. 12.
Determining Stray Power of a Transmission Line.* D. D. Ewing. (17) Jan. 12.
Long Spans Permitted by Steel Wires a Saving.* L. M. Klauber. (27) Jan. 12.
Calculations in Use of Projectors.* Waldo C. Cole. (111) Jan. 15.
Problems of Factory Lighting.* Romaine W. Myers. (111) Jan. 15.
A "Density-Cell" with Slight Local Action.* Ch. Fery. (Abstract of paper read before the Société Internationale des Electriciens.) (73) Jan. 18.
Cable Fault Localization in Practice.* O. M. W. Hutchison. (26) Jan. 18.
Iron Commutators. Frederick Murgatroyd. (26) Jan. 18.
Turbo-Rotor Cap-Rings.* R. Roberts. (73) Serial beginning Jan. 18.
A Solution for an Acceptance-Test Problem: Simple Method of Correcting Generator-Unit Load—Characteristic Curve for Variations in Speed—of Entire Accuracy When the Magnetic Circuit is Highly Saturated. W. B. Kouwenhoven. (27) Jan. 19.
Obtaining Power Factor by Use of Wattmeter.* E. G. Barrington. (27) Jan. 19.
Fires in Turbo-Generators. M. A. Walker. (64) Jan. 22.
Differential Electro-Magneto Clutch.* (12) Jan. 25.
New Night Lights for Pullman Cars.* (15) Jan. 25.
The Potentialities of a National Power Scheme. Ernest P. Hollis. (Abstract of paper read before Warwickshire Branch of the Assoc. of Min. Elec. Engrs.) (22) Jan. 25.
The Selection of an Electricity Meter. W. G. N. (26) Jan. 25.
Electrical Properties of Vulcanized Fiber. William Eves, 3d. (27) Jan. 26.
Successful Operation of Secondary Networks.* S. Bingham Hood. (27) Jan. 26.
A New Standard of Current and Potential.* Chester T. Allcutt. (42) Feb.
A Thermo-electric Standard Cell. C. A. Hoxie.* (42) Feb.
Automatic Control of High Temperature. R. P. Brown. (Abstract of a paper read before the Faraday Soc. of London.) (62) Feb.
Commutation in Alternating-Current Machinery.* Marius C. A. Latour. (42) Feb.
Factory Lighting Codes and Rules; a Review of Progress, and the Regulations of Wisconsin, New York, Pennsylvania and New Jersey.* C. E. Clewell. (9) Feb.
Measurement of Power Loss in Dielectrics of Three-Conductor High-Tension Cables. F. M. Farmer.* (42) Feb.
Rating and Selection of Oil Circuit Breakers.* E. M. Hewlett, J. M. Mahoney and G. A. Burnham. (42) Feb.
The Character of the Thermal Storage Demand Meter.* P. M. Lincoln. (42) Feb.
The Polyphase Shunt Motor.* W. C. Korthals Altes. (42) Feb.
The Secomor: a Kinematic Device Which Imitates the Performance of a Series-Wound Polyphase Commutator Motor. V. Karapetoff. (42) Feb.

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* Illustrated.

Electrical—(Continued).

Astoria Underground Electrical System. R. J. Davidson. (111) Feb. 1.
Comparative Experiments on the Audion.* G. Vallauri. (Abstract of article in *L'Ettrotecnica.*) (73) Feb. 1.
Electric Winding Engines.* John F. Perry. (Paper read before National Assoc. of Colliery Managers and Assoc. of Min. Elec. Engrs.) (22) Feb. 1.
Resistances for Starters and Controllers. (26) Feb. 1.
War Service of Electrical Energy.* Robert Sibley. (111) Feb. 1.
D. C. Calibration of Power-Factor Meters.* Thomas W. Varley. (27) Feb. 2.
Simplifying Transmission-Line Calculations.* T. A. Wilkinson. (27) Feb. 2.
Alternating-Current Automatic Starters for Squirrel-Cage Induction Motors.* W. H. Patterson. (64) Feb. 5.
Electric Ploughing.* (26) Serial beginning Feb. 8.
Bulk Supply Generating Station at Mouth of Mine.* (27) Serial beginning Feb. 9.
Combining Loads to Gain Economies of Large Units and High Diversity Factor.* (17) Serial beginning Feb. 9.
Concrete Poles Carry 22 000-Volt Power Line.* (27) Feb. 9.
Interpole Mill Motors *versus* Non-Interpole.* W. R. Runner. (27) Feb. 9.
Self-Inductance of Long Reactance Coils. H. B. Dwight. (27) Feb. 9.
Synchronizing Stations to Reduce Interruptions. (27) Feb. 9.
Present Status of Insulator Depreciation.* C. E. Oakes. (111) Feb. 15.
Electricity as Applied in the U. S. Navy.* (64) Feb. 19.

Marine.

National Electric Code—Marine Works. (111) Jan. 1.
American International Shipbuilding Corporation, Philadelphia.* (13) Jan. 3.
Merchants Shipbuilding Corporation at Bristol, Penn.* (13) Jan. 3.
Submarine Boat Corporation, Newark, N. J.* (13) Jan. 3.
Some Insufficiently Considered Details of Ship Construction and Equipment.* C. Waldie Cairns. (Paper read before the North-East Coast Inst. of Engrs. and Shipbuilders.) (11) Jan. 4.
Shipbuilding Expedited by Electric Service.* David Elwell. (27) Jan. 5.
Repairing German Vandalism by Electric Welding.* E. P. Jessop. (From *Journal* of the Am. Soc. of Naval Engrs.) (11) Jan. 11.
350-B. H. P. Kromhout Marine Engine.* (12) Jan. 11.
Giant Crane for the United States Navy.* W. H. Shepard. (72) Jan. 17.
Notes on Operation of Submarine Diesel Engines. F. C. Sherman. (Reprinted from *Journal* of the Am. Soc. of Naval Engrs.) (11) Jan. 18.
Gas-Fired Shipyard Furnace Burning Over 3 000 Cu. Ft. per Hour Betters Oil-Firing Cost with Oil at 6 Cents per Gallon.* William J. Harris. (24) Jan. 19; (20) Feb. 7.
Adjusting Marine-Engine Bearings.* William M. McRobert. (64) Jan. 22.
Building a Town to House Three Thousand Shipbuilders.* (13) Jan. 31.
Making Ship Forgings at the Balboa Shops.* (62) Feb.
Successful Handling of a Difficult Salvage Task.* (46) Feb. 9.
Are We Building Real Ships?* A. C. Lacet. (46) Feb. 16.
The Propulsion of Ships. A. T. Wall. (19) Feb. 16.
Electricity as Applied in the U. S. Navy.* (64) Feb. 19.
New Shipyards Built on Canadian Pacific Coast.* R. Mackay Fripp. (13) Feb. 21.
A Ship Within a Ship.* (46) Feb. 23.
Les Constructions Navales en Béton Armé.* G. Espitallier. (33) Serial beginning Jan. 5.
Réparation des Navires allemands Internés aux Etats-Unis et Endommagés par leur Equipages.* (33) Jan. 26.

Mechanical.

A Comparison of the Working Costs of the Principal Prime Movers. Oswald Wans. (Abstract of a paper read before the Inst. of Mech. Engrs.) (21) Jan.
The Advantages of Modern Sand Blasting.* A. W. Peterson. (62) Jan.
Plain Knee Type and Similar Milling Machines.* M. H. Williams. (25) Jan.
Lodge and Shipley Control System.* D. M. Perrill. (9) Jan.
Relation of Quantity Production to Cost; Labor Analysis of Manufacturing a Shaft in Lots of 1 to 200 Pieces. A. G. Popcke. (9) Jan.
Firing Glazes.* Armand De Gallaix. (76) Jan. 1.
Fundamental Principles of Combustion. (76) Serial beginning Jan. 1.
New Method of Increasing the Evaporation in Boilers.* Carl Hering. (64) Jan. 1.
Acres of Shops to Form Ordnance Base in France.* (13) Jan. 3.
Build Hundred and Ten-Inch Plate Mill in Six Months.* (13) Jan. 3.
Correcting Dies That Failed to Draw.* A. C. Lindholm. (72) Jan. 3.
Locating Small Holes Accurately in Die Work.* Hugo F. Pusep. (72) Jan. 3.
Manufacturing Operations in Making a Gasoline Motor.* (72) Jan. 3.
Overhauling the Gnome Airplane Engine.* (72) Jan. 3.
A Safety-First Opening for Metal Workers.* (101) Jan. 4.

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* Illustrated.

Mechanical—(Continued).

An Agricultural Power Unit: Some Factors Governing the Design of a Small Tractor.* Alan E. L. Chorlton. (Paper read before the Inst. of Automobile Engrs.) (11) Jan. 4.

Smokeless Boilers for Fuel Conservation.* (101) Jan. 4.

Some Notes on Coal Testing.* G. W. Stubbings. (26) Jan. 4.

Testing Machines for Aeroplane Manufacture.* (11) Jan. 4.

The Escape of Exhaust Gas in Two-Stroke Cycle Engines. Guy B. Petter. (11) Jan. 4.

Determining Boiler Efficiency by Co_2 Analyses and Flue Temperatures. Haylett O'Neill. (64) Jan. 8.

Mono-Rail Telpher at the Warrington Gas-Works.* (66) Jan. 8.

Notes on High-Pressure Distribution. J. Beveridge. (Paper read before Western District of the Scottish Junior Gas Assoc.) (66) Jan. 8.

Operation and Maintenance of Elevators-Winding-Drum Machines.* R. H. Whitehead. (64) Jan. 8.

Use of Crude Naphthalene as Fuel for Internal Combustion Engines. J. H. Willis. (66) Jan. 8.

Boring and Reaming Tools for 220- and 270-mm. French Shells.* James Forrest. (72) Jan. 10.

The Micrometer Head in Toolwork.* Hugo F. Pusep. (72) Jan. 10.

Use of Diamond Tools in the Shop.* Frank A. Stanley. (72) Serial beginning Jan. 10.

A New Type of Enclosed Motor.* (26) Jan. 11.

Chimney Size and Air for Fuel Combustion.* (101) Jan. 11.

Electrically-Driven Cement Works.* B. J. Day. (Abstract of paper read before the Inst. of Engrs. and Shipbuilders in Scotland.) (26) Jan. 11.

Repairing German Vandalism by Electric Welding.* E. P. Jessop. (From *Journal* of the Am. Soc. of Naval Engrs.) (11) Jan. 11.

Strength of Weld in Genuine Wrought Iron Pipe.* (101) Jan. 11.

In Any Case Where Toluol is to be Removed Candle Power Standard Should be Eliminated or Made so Low It will not Interfere with Operations. R. S. McBride. (24) Jan. 12.

Operating Characteristics of Motor-Driven Planers.* C. E. Clewell. (27) Jan. 12.

Analysis by Weight, and Air Theoretically Required in Fuel Oil Furnace.* Robert Sibley and Chas. H. Delany. (111) Jan. 15.

Constructing a Home-Made Crude Benzol Recovery Plant at the Redditch Gas-Works. C. F. W. Rendle. (Paper read before the Midland Junior Gas Assoc.) (66) Jan. 15.

Multi-Stage Compression Plant of Central Cold Storage Co.* (64) Jan. 15.

Origin and Properties of Ceramic Fuels. J. F. Kohout. (76) Jan. 15.

Selection of Coal and Ash Conveyors.* H. E. Birch. (64) Jan. 15.

Using Instruments in Determining Proper Burning Conditions.* S. C. Karsen. (76) Jan. 15.

Giant Crane for the United States Navy.* W. H. Shepard. (72) Jan. 17.

Manufacturing a Steel Chair.* G. F. Wetzel. (72) Jan. 17.

Uses of an Economic Department in a Machine-Tool Plant. Ludwig W. Schmidt. (72) Jan. 17.

Cleaning Blast-Furnace Gas for Boilers and Stoves. A. Lennox Leigh. (Paper read before the Cleveland Inst. of Engrs.) (22) Jan. 18.

"Emcol" Enclosed Motors.* (73) Jan. 18.

How the Valve Works.* (101) Jan. 18.

Large Crank Pin Turning Machine.* (12) Jan. 18.

New Type "Hunt" Electric Industrial Truck.* (73) Jan. 18.

Notes on Operation of Submarine Diesel Engines. F. C. Sherman. (Reprinted from *Journal* of the Am. Soc. of Naval Engrs.) (11) Jan. 18.

Some Safety Devices for Steam Turbines.* (12) Jan. 18.

Use of Coke-Oven Gas in Gas Engines. Samuel Stonier. (Abstract of address before Western Section of the Coke-Oven Managers' Assoc. at Crewe.) (22) Jan. 18.

Gas-Fired Shipyard Furnace Burning Over 3 000 Cu. Ft. per Hour Betters Oil-Firing Cost with Oil at 6 Cents per Gallon.* William J. Harris. (24) Jan. 19; (20) Feb. 7.

New High-Pressure Joliet Plant.* (64) Jan. 22.

Oxy-Acetylene and Electric Welding and Cutting Processes in Locomotive Works. A. F. Dyer. (Paper read before Canadian Railway Club.) (86) Jan. 23; (96) Jan. 10; (18) Feb. 9.

Interchangeability, Tolerances and Finish. J. P. Brophy. (72) Jan. 24.

Making Typewriter Parts.* M. E. Hoag. (72) Serial beginning Jan. 24.

The Manufacture of Riche Gas from Wood in Three Rivers, P. Q. L. H. Bacque. (96) Jan. 24.

A Constant Torque Clutch.* (73) Jan. 25.

Notes on Welding Systems. James Caldwell. (Abstract of paper read before the Inst. of Engrs. and Shipbuilders in Scotland.) (26) Jan. 25.

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Utility of Motor Tractors for Tillage Purposes. Arthur Amos. (Paper read before the Inst. of Mech. Engrs.) (11) Jan. 25.
Double Gas Output per Ton of Coal Obtained by Making Water Gas in Continuous Vertical Retorts.* Henry M. Balsam. (24) Jan. 26.
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Comparative Values of Coke-Oven Crude Benzols. B. Wilson Haigh and Harold Lamb. (Paper read before the Midland Section of the Coke-Oven Managers' Assoc.) (66) Jan. 29.
Gas-Engine Troubles and Remedies. A. L. Brennan, Jr. (64) Jan. 29.
Running a Heat Balance on a Paving Brick Kiln.* S. C. Karzen. (76) Jan. 29.
Condensers with Seventy-Foot Water Level Variation.* F. R. Brosius. (64) Jan. 29.
A Graphic Method for the Design of Cone Pulleys.* Raymond S. Brown. (72) Jan. 31.
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Laminated Steel-Spring Proportions. H. H. Kennedy. (72) Jan. 31.
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Gravity Conveyors for Shell Forgings.* H. E. Floercky. (62) Feb.
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Application of Motors to Steel-Mill Operations.* C. E. Clewell. (27) Feb. 2.
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Determining the Most Satisfactory Formula for Measuring the Flow of Natural Gas Through Pipe Lines. E. O. Hickstein. (24) Feb. 2.
113 Miles of Pipe Line Completed in Record Time Despite Adverse Conditions.* R. E. Morrison. (24) Feb. 2.
Electric Vehicle Performance in Winter. Kennedy Rutherford. (19) Feb. 2.
Alternating-Current Automatic Starters for Squirrel-Cage Induction Motors.* W. H. Patterson. (64) Feb. 5.
Buying an Ash-Handling System. Herbert E. Birch. (64) Feb. 5.
Operating Costs of Electric Elevators.* Charles W. Naylor. (64) Feb. 5.
The Lubrication of Steam Turbines.* (From *Lubrication.*) (64) Feb. 5.
High Temperature Drying; Results of Scientific Treatment of Various Products Dried in Heated Air at 200 to 1 000 Degrees. Burton S. Harrison. (Abstract of paper read before Am. Soc. of Heating and Ventilating Engrs.) (101) Feb. 8.
A Compound Harmonic Motion Machine.* William F. Rigge. (19) Serial beginning Feb. 9.
A Way to Enormous Coal Economies.* (46) Feb. 9.
Auto-Tower Truck with Engine-Raised Tower.* S. L. Foster. (17) Feb. 9.
Conservation of Fuel Through Smoke Regulation. J. W. Henderson. (Abstract of paper read before Section D of the Am. Assoc. for the Advancement of Science.) (18) Feb. 9.
The Briquetting of Anthracite.* W. P. Frey. (45) Feb. 9.
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Building Motors with General-Purpose Machines.* (72) Serial beginning Feb. 14.
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Powdered Coal for Central Station Use. W. J. Santmyer. (111) Feb. 15.
Entire Factory Equipped with Gas Lights and Added to the Long List of Satisfied Gas Users. S. E. Wardell. (24) Feb. 16.
Reducing Costs of Fuel and Boiler Maintenance.* S. B. Applebaum. (27) Feb. 16.
High Carbonizing Results Obtained in England by Steaming the Charge in Glover-west Vertical Retorts.* Norton H. Humphrys. (24) Feb. 16.
Absorption Refrigerating Machines.* F. C. Spangler. (Abstract of paper read before N. Y. Engrs.' Protective Assoc.) (64) Feb. 19.
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Lubrication of Ball Bearings.* Otto Bruenauer. (72) Serial beginning Feb. 21.

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Cambridge Experience Demonstrates Practicability of Recovering Light Oils in small, Inexpensive Stills. Isaac I. Haddock. (Paper read before the New England Assoc. of Gas Engrs. in Boston.) (24) Feb. 23.
Modern Abrasive Wheels.* Raymond Francis Yates. (19) Feb. 23.
A Fifty-Thousand Square Foot Condenser.* (64) Feb. 26.
Measuring High Pressures with Dead Weight.* Sanford A. Moss. (64) Feb. 26.
Essais sur la Détermination du Pouvoir Eclairant Relatif du Gaz Débenzolé et sur l'Influence du Débenzolage sur l'Intensité Lumineuse des Becs à Incandescence.* R. Busquet. (33) Serial beginning Jan. 5.

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Spiegeleisen in Place of Ferromanganese. Edwin F. Cone. (20) Jan. 3.
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Melting of Brass in the Induction Furnace.* G. H. Clamer. (Abstract of paper read before Philadelphia Foundry Men's Assoc.) (72) Jan. 3.
The Booth-Hall Electric Steel Furnace.* (20) Jan. 3.
The Manufacture of Pattern Castings.* Henry M. Lane. (20) Jan. 3.
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Progress in the Metallurgy of Copper. H. C. H. Carpenter. (29) Serial beginning Jan. 4.
Ferromanganese and Spiegeleisen. George C. Stone. (16) Jan. 12.
Malleable Cast Iron. E. Adamson. (Abstract of paper read before the Staffordshire Iron and Steel Inst.) (57) Jan. 18; (22) Jan. 18.
The Influence of Heat Treatment on the Electrical and Thermal Resistivity and Thermo-Electric-Potential of Some Steels. Edward D. Campbell and William C. Dowd. (Paper read before the Iron and Steel Inst.) (105) Jan. 15.
Acidity Determination in Water, Leach Liquors, Mine Waters, Etc. James J. Rankin. (105) Jan. 15.
The Sulphuric Acid Situation in the United States. Lewis B. Skinner. (105) Jan. 15.
The Commercial Aspects of the Recovery of Potash in the Manufacture of Pig-Iron. Kenneth M. Chance. (Paper read before the Cleveland Inst. of Engrs.) (22) Jan. 18.
The Greaves-Etchells Electric Furnace. (12) Jan. 18.
Some Unusual Features in the Micro-Structure of Wrought Iron.* Henry S. Rawdon. (Reprinted from *Technologic Papers No. 97*, of the U. S. Bureau of Standards.) (11) Jan. 18.
The Automatic Control and Measurement of High Temperatures. R. P. Brown. (Abstract of paper read before the Faraday Soc.) (72) Jan. 24.
Recovery of Potash from Blast-Furnace Gases. R. A. Berry and D. N. McArthur. (Abstract of paper read before West of Scotland Iron and Steel Inst. and Soc. of Chemical Industry.) (22) Jan. 25.
The Utilization of Manganese Ores in Sweden. Joh. Harden. (Abstract of a paper read before a meeting of Chemists in Sweden.) (73) Jan. 25.
Tilting Metal Mixers and Steel Furnaces. H. Stonewall Jackson. (Abstract of a paper read before the Cleveland Inst. of Engrs.) (22) Jan. 25.
The Forging of an Off-Set Jaw.* J. U. Hunter. (72) Jan. 31.
The Grinding Wheel In the Foundry. W. T. Montague. (Abstract of paper read before Am. Foundrymen's Assoc.) (20) Jan. 31.
Recovery of Spelter and the Treatment of Retort Residues. Edward Mackay Johnson. (105) Feb. 1.
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Electric and Converter Castings Compared. C. R. Messinger. (Abstract of paper read before Am. Foundrymen's Assoc.) (20) Feb. 14.
Electric Drying Ovens in a Rod Mill.* (20) Feb. 14.
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Zinc-Smelting Possibilities in Tonkin, Indo-China. A. Lochard. (Abstract of paper in *Bulletin*, Soc. de l'Ind. Minerale.) (16) Feb. 16.

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Protective Screens for Furnaces.* J. V. Hunter. (72) Feb. 28.
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Anthracite and Bituminous Coal Storage.* Horace Goldstein. (45) Jan. 5.
Bauxite in the Coastal Plain of Georgia.* H. K. Shearer. (Abstract of report.) (16) Jan. 5.
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The Search for New Oil Pools in the United States.* Dorsey Hager. (16) Jan. 5.
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Modern Methods for the Storage of Coal. George Frederick Zimmer. (11) Jan. 11.
New Washery at the Works of the Blaenavon Company, Limited.* (22) Jan. 11.
Organizing Safety Work in Mines. H. M. Wilson and J. R. Fleming. (57) Jan. 11.
Some Points of Interest to Northumberland and Durham Colliery Engineers. A. C. Nelson. (Abstract of paper read before North of England Branch of the Assoc. of Min. Elec. Engrs.) (73) Jan. 11.
An Up-to-Date Coal-Mine Power Plant.* Dever C. Ashmead. (45) Jan. 12.
Block Signal System for Coal Mines.* Frank Huskinson. (45) Jan. 12.
Efficiency Engineering for Coal Mines. C. H. Elsom. (Abstract of paper read before West Virginia Coal Min. Inst.) (45) Jan. 12.
Hoisting-Ropes. M. H. Sigafoos. (Abstract of paper read before the Min. Section of the National Safety Council.) (103) Jan. 12.
Spontaneous Heating of Coal.* George Knox. (66) Jan. 15.
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Mining Thin Coals. J. F. Kellock Brown. (Abstract of *Bulletin No. 15*, Dept. of Mines, Ottawa.) (57) Jan. 18.
Andes Copper Mining Co.'s Development at Potrerillos, Chile.* James E. Harding. (16) Jan. 19.
The Bogomolovsky Copper Mines, Russia.* N. T. Truschkoff. (103) Jan. 19.
Relining a 20-Ft. Diameter Shaft.* G. B. Tristram. (22) Jan. 25.
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Oil and Gas Fields of Illinois.* H. A. Wheeler. (16) Jan. 26.

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Pressure in the Formation of Ore Deposits.* Stephen Taber. (103) Jan. 26.
Pyrrhotite Deposits of Southwest Virginia. J. A. Van Mater. (16) Jan. 26.
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Electric Winding Engines.* John F. Perry. (Paper read before National Assoc. of Colliery Managers and Assoc. of Min. Elec. Engrs.) (22) Feb. 1.
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Manganiferous Iron Mining in the Cuyuna District, Minnesota.* P. M. Ostrand. (16) Feb. 9.
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Reproduction Cost in Industrial Appraisement. Charles W. McKay. (9) Jan.
Bibliography on the Extraction of Potash from Complex Mineral Silicates, Such as Feldspar, Leucite and Glauconite (Greensand Marl). E. C. Buch. (105) Jan. 1.
A Call for State Supervision of Engineering. Clarence T. Johnston. (13) Jan. 3.
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Natural Lighting for Work Spaces in Shops.* C. E. Clewell. (101) Jan. 4.
Bonus System for the Saving of Coal. Walter N. Polakov. (27) Jan. 5.
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INSTITUTED 1852

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PAPERS AND DISCUSSIONS

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THE ECONOMICS OF STEEL ARCH BRIDGES

By J. A. L. Waddell, M. Am. Soc. C. E.

To be Presented May 1st, 1918.

Synopsis.

Up to the present time, nothing at all certain has been known concerning the economics of steel arch bridges, the weights of metal required to build them, or how they compare in cost with corresponding steel truss bridges.

The objects of this paper and its anticipated discussions are to settle finally every important economic question that can arise in the designing of steel arches; to give formulas and diagrams for determining, with a fair amount of accuracy, the weights of metal in both arch bridges as a whole and the arches themselves; and to indicate the relations between the weights and costs of arch bridges in comparison with those of corresponding truss bridges.

There are eight economic problems set for solution, and all of them have been solved—the first two by using certain formulas given in the writer's new book, "Bridge Engineering", and the other six by a large number of special arch designs and the resulting estimates of weights of metal. Incidentally, during the investigation, there have arisen and have been solved a few minor questions which may properly

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Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

be termed side issues. The computations have been made for both railway and highway arch bridges; and the weights of metal are plotted for both carbon-steel and nickel-steel structures. Several diagrams are given to show the percentage effects of weight increase due to departure from economic conditions.

The need for the special knowledge concerning arch bridges presented in this paper has been recognized during the last three decades by American structural steel engineers; but the authors of books on bridges (the writer included) have hitherto avoided the issue because of the immense amount of work involved in the solution of the various problems. The writer has tried of late years on several occasions to persuade some of his brother engineers to undertake the task; but, not meeting with any success, he finally decided to do the work himself. The results of his efforts are herewith presented to the members of the Society with a most earnest request for a thorough discussion, particularly by those who specialize in bridgework.*

Concerning the economics of steel arches, very little, indeed, is known, the reasons being that comparatively few such structures have been built in America, and that the subject of economics in bridge design is a study to which, generally speaking, but slight attention has been paid until late years. Occasionally, an American bridge engineer builds a steel-arch structure; but usually simple-truss spans are adopted because their approximate weights and their economics are on record. The writer is of the opinion that if more were known generally concerning the weights of metal in steel-arch structures, their economic functions, and their comparative economy in respect to the corresponding simple-truss structures, the esthetic type would be adopted more frequently, in spite of the greater labor it involves in both designing and construction. An arch is almost always a handsomer structure than an ordinary truss bridge; and the time has arrived for all American engineers to pay proper attention to the important feature of esthetics in the preparation of designs.

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* As it would be out of the question to publish the great mass of graphic calculations of stresses, diagrams of stresses and sections, tabulated estimates of weights of metal, and other computations which were prepared specially for this paper, copies of them are filed in the archives of the Society, and as the original dimensions of the paper have been reduced in the interest of economy of publication, the memoir as first written will also be so filed.

The writer desired to quote three pages from the chapter relating to Arch Bridges from his book "Bridge Engineering", giving ten equations which form the basis of the solution of the first two problems discussed, and an explanation of how they were established, but this was prevented by the requirements of the Publication Committee. It will be necessary, therefore, for the reader to refer to the author's book in order to comprehend the *modus operandi* of solving the said two problems.

The economic problems concerning the design of steel arches which still require solution are:

First.—The economic ratio of rise to span length;

Second.—The economic depths for the ribs;

Third.—The economic location for the crown-hinge in three-hinged, spandrel-braced arches;

Fourth.—The ratios of weights of metal required for the solid-rib, the braced-rib, and the spandrel-braced types;

Fifth.—The ratios of weights of metal required for the hingeless, the two-hinged, and the three-hinged types;

Sixth.—The economics involved by making arches three-hinged for the dead load and two-hinged for the live load;

Seventh.—The economy of the cantilever arch with suspended end spans, as compared with an ordinary arch and two flanking simple-truss spans; and

Eighth.—The ratios of weights of metal required for certain portions of arch bridges as compared with the corresponding portions of simple-truss bridges of the same span and the same live-load carrying capacity.

Problem No. 1.

Up to the present time, no reliable information has been available concerning the economic ratios of rise to span length, a few computers recognizing that it lies between the limits of 15 and 30%; but no systematic investigation of the question, as far as the writer knows, has ever been made.

However, by the use of ten equations* for three-hinged arches, the weights of metal for both the solid-rib and the braced-rib types of various span lengths, and having any ratio of rise to span, any depth of rib, and any live load or dead load, can be found readily and with considerable accuracy. The formulas given by these equations are based on the writer's specifications for designing†; which specifications, it is generally acknowledged, are substantially in accordance with the best American bridge engineering practice. From these equations, by the substitution of certain assumed values, can be found both the economic ratios of rise to span length and the economic depths of arch ribs.

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* Given in Chapter XXVI of the writer's "Bridge Engineering."

† "Bridge Engineering", Chapter LXXVIII.

In order to cover effectively the ordinary range of span lengths for arch designing, it was necessary to compute for three lengths, *viz.*, 200, 500, and 800 ft.; and, in order to include all ordinary structures, it was decided to determine the economic functions for both steam-railway bridges and combined highway and electric-railway bridges. For steam-railway bridges, double-track structures to carry Class-60 live load were adopted; and for combined highway and electric-railway bridges there was chosen a deck, 60 ft. wide from out to out, having at the middle a double-track electric railway, on each side of the latter an 11-ft. clear space for vehicles, and on the outside of each roadway an 8-ft. sidewalk, the entire roadway, including the track space, being paved with creosoted blocks resting on a reinforced concrete base, and the sidewalks being of reinforced concrete slabs.

The work involved in the investigation was, of necessity, reduced to a minimum, being great enough, in all conscience, as it was; hence solid-rib arches were computed for spans of only 200 ft., because structures of that type of longer span would be uneconomical. In some cases, owing to the cut-and-try method which had to be adopted, many assumptions of ratios of rise to span were tested; but, in order to save space, the unnecessary results have not been recorded, three only for each case serving the purpose of determining the minimum.*

In finding the weights of metal, it was necessary first to assume the depths of the arch ribs, and afterward to test them for economy; but, fortunately, in every case the first guess was almost exactly correct. These checks on the economic depths of arch ribs are discussed hereinafter.

In computing the economics of arches, it is not sufficient to ascertain merely the weights of metal in the arch ribs, for it is necessary to take into consideration also the weights of metal in the superimposed columns and the vertical sway bracing between them; and in comparing the weights of arches with those of the corresponding simple trusses, the former must be increased by the weights of such columns and their vertical sway bracing. In general, it may be assumed that the weight of the entire lateral system in a simple-truss bridge will offset that in the bracing of the floor system, plus that of the rib flanges of the corresponding arch structure, plus that of the other diagonals between the arch ribs. The error involved in this assumption is so small that it will not affect the correctness of the comparisons made in this investigation.

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* See manuscript on file in the Society's archives.

The problem of determining the economic ratio of rise to span is not as simple as it might appear at first thought; for it is a compound one, being dependent on the conditions precedent. These may be divided into four cases, *viz:*

First.—When the rocky sides of the chasm to be spanned are practically vertical, with the grade line about tangent to the crown of the top chord of the arch. In this case, as previously indicated, the weight of the superimposed columns and their bracing must be considered with that of the arch rib in determining the economic rise.

Second.—In the case of a half-through structure, where the variations in the sum of the weights of hangers and columns are comparatively slight for changes in rise, and where, consequently, the economics are dependent mainly on the weight of the arch rib alone.

Third.—When the grade line is far above the crown of the arch, and, consequently, the greater the rise the less the weight of the superimposed columns and their bracing. This is just the opposite condition to that of the first case, because, in that one, the greater the rise the greater is the average length of the spandrel columns.

Fourth.—When the chasm is decidedly V-shaped. In this case the grade line may be either tangent to, or well above, the crown of the top chord.

These four cases have been considered separately.*

Case No. 1.—From Table 1 it may be concluded that for braced-rib arches the economic ratio of rise to span for all spans between 200 and 800 ft. may be taken at 0.225, without making any appreciable error. The calculations, however, show that within the limits of 0.2 and 0.25 there is very little variation of arch weight. In many cases one cannot exercise much choice in the selection of the rise for an arch, because the profile of the crossing and the adopted grade

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* In the original memoir are given the designing data and the tabulated results of substitution in formulas for seven cases of both railway and highway bridges and covering both solid-rib, and braced-rib arches, also a few notes concerning certain short cuts that were used in the computation. Each table contains three records, the middle one indicating the economic ratio of rise to span, because it records the minimum weight of metal, in pounds per linear foot per side.

TABLE 1.—Summary of Results of Economic Rise Investigations for Braced-Rib Arches.

Span, in feet.	Economic Ratios of Rise to Span Length.	
	Steam-railway structures.	Combined highway and electric railway structures.
200	0.225	0.225
500	0.225	0 225
800	0.240	0.240
Averages	0.230	0.230

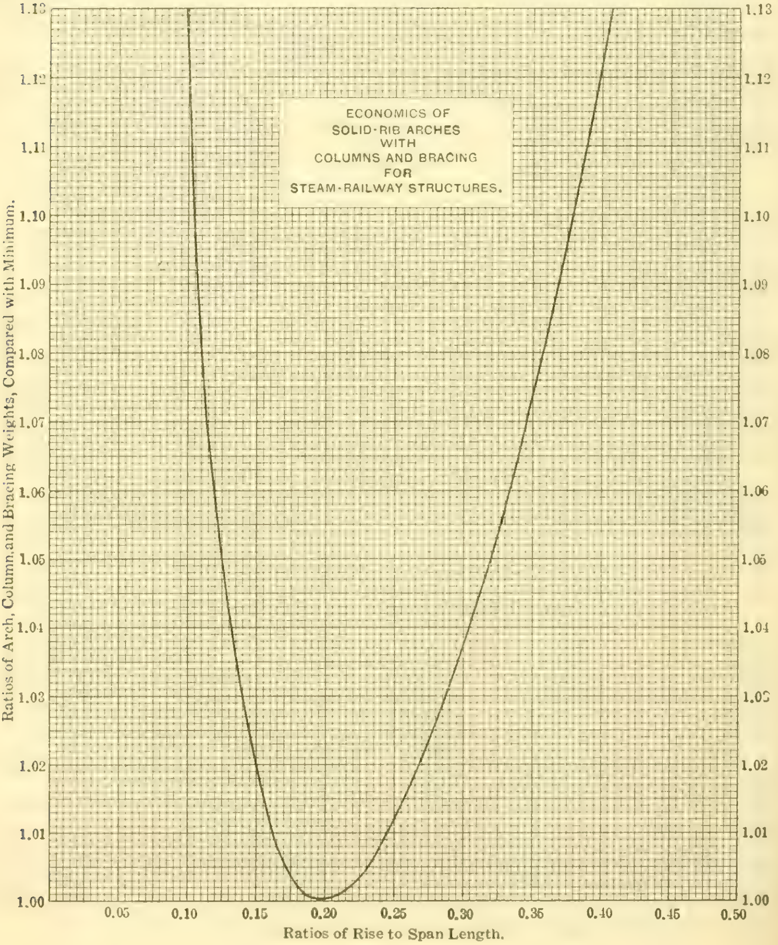


Fig. 1.

line of floor will be the governing factors. Under such conditions one should use a ratio as near to the economic one as practicable. Fortunately, as far as the matter of esthetics is concerned, such ratio is not a vital feature; and the calculations show, as just indicated, that it can be modified considerably without greatly augmenting the total cost of the structure.

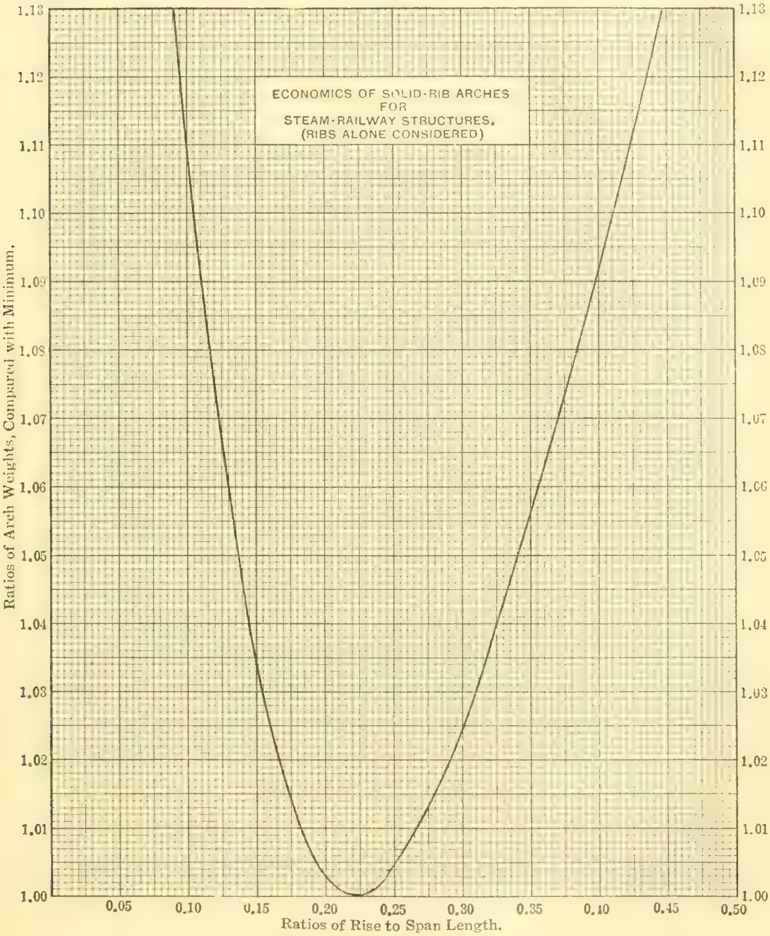


FIG. 2.

For solid-rib arches, the most economic ratio of rise to span may be taken as 0.2, and the ordinary range as from 0.175 to 0.225. In order to show graphically the economics of solid-rib arch bridges, Figs. 1 and 2 have been prepared, the former being applicable when the superimposed columns and their bracing are considered, and the latter when only the ribs themselves are under discussion. The abscissas represent the ratios of rise to span length, and the ordinates the corresponding percentages of metal required, the percentage for the minimum weight being one hundred.

Figs. 3 and 4 present the same data for braced-rib arches as are shown in Figs. 1 and 2 for solid-rib arches.

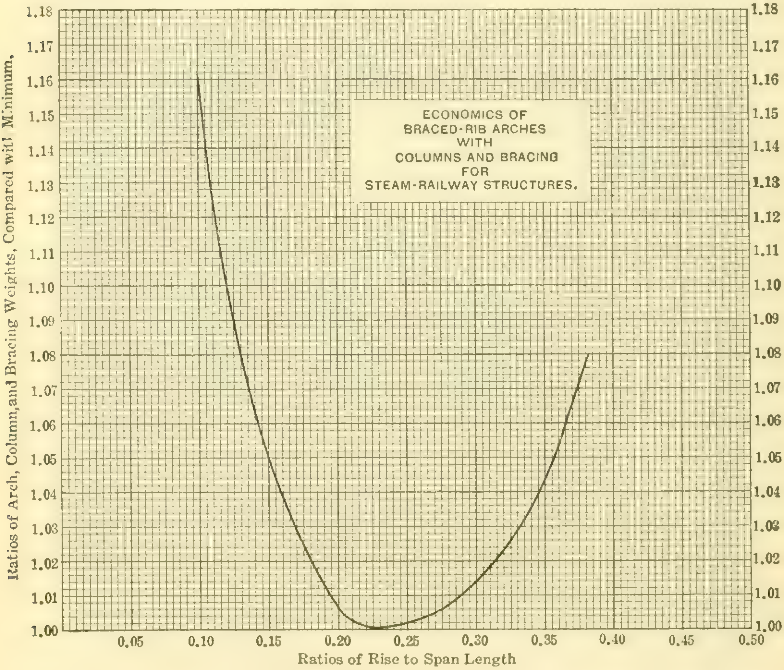


FIG. 3.

Another deduction that may be made from Table 1 is that the economic ratio of rise to span is independent of the kind of traffic which the structure carries; and the calculations have indicated that it is independent also of the size of the loading.

Case No. 2.—A systematic extension of the economic calculations for the 200-ft. and the 500-ft. spans showed that, for the solid-web type, the economic ratio of rise to span (when merely the weight of the arch itself is considered) is 0.225; and for the braced-rib type it is 0.3. A variation of 0.025 in either direction, however, does not greatly increase the weight of metal.

Case No. 3.—When the grade line is well above the crown of the arch, as shown in Fig 5, it is evident that the greater the rise, the less will be the average length of the superimposed columns and bracing—also that the greater the vertical distance between crown and grade the greater the saving in metal weight per foot of vertical reduction in height of columns. This last consideration, though, is of minor importance, and would affect very slightly, indeed, the

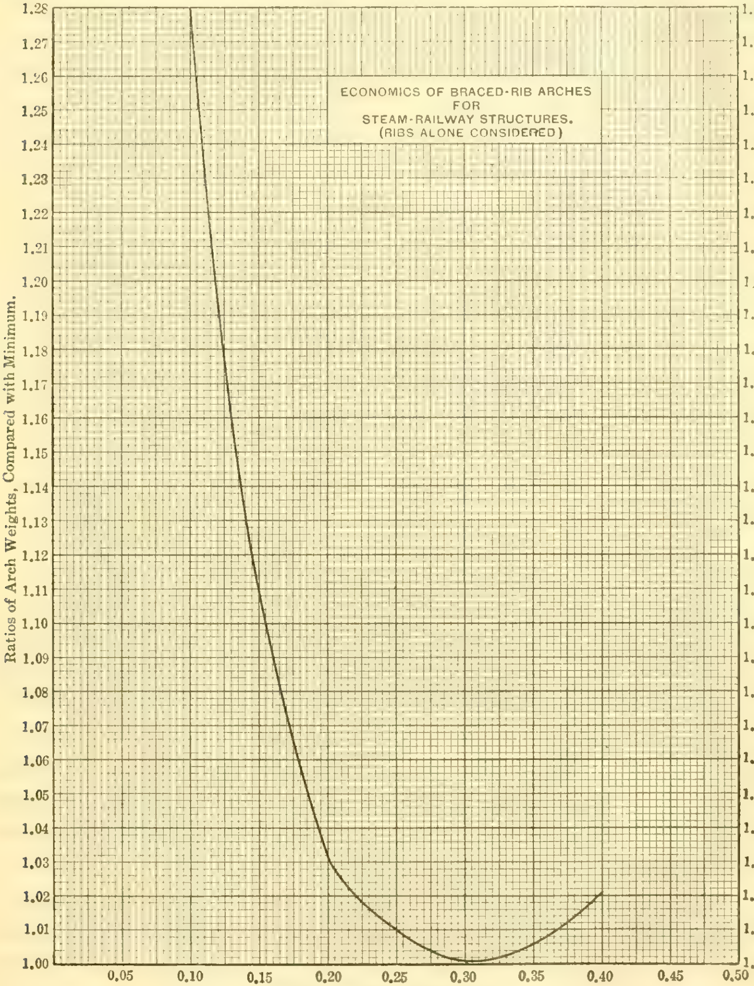
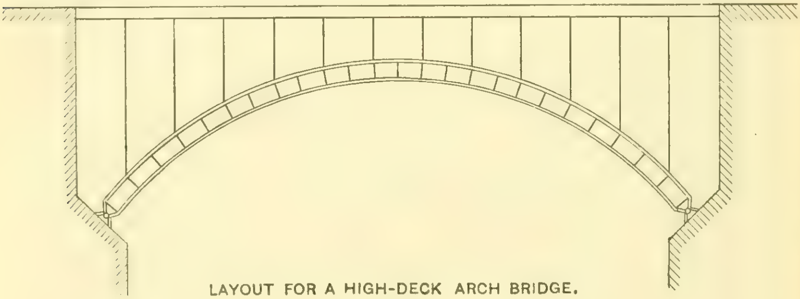


FIG. 4.

economic ratio of rise to span. For the solid-rib type, that ratio for high-decked arches (those where the grade is well above the crown) will vary from about 0.25 to 0.28, and for the braced-rib type from about 0.35 to 0.38.

Case No. 4.—Where the rocky sides of the cañon are V-shaped, there is only one way to determine the economic location of the springing points, and that is by trial; but the results of the investigations in this paper will enable the computer to reduce to a minimum the number of trials required, and will cut down materially the calculations necessary for the solution of the problem.

For spandrel-braced arches it will suffice for economy of metal to make the rise of the bottom chord from 20 to 25% of the span length.



LAYOUT FOR A HIGH-DECK ARCH BRIDGE.
FIG. 5.

In respect to the economic ratios of rise to span for two-hinged arches, there is no reason which militates in any way against the correctness of the assumption that they will be practically the same as those for three-hinged arches, because the two types are very similar; and, moreover, they are likely to be made still more similar in future constructions by hinging the crown at mid-depth for the dead-load stresses and afterward making both the upper and the lower chords continuous for the live-load stresses.

As for the economic ratio of rise to span for hingeless arches, in making the calculations for the 500-ft. span in Problem No. 5, it was assumed to be the same as for three-hinged arches, computing in both cases along the mid-line of the rib; but some special supplementary calculations, involving an entirely new layout and design, showed that it is somewhat greater. It may be taken as 0.28 when the grade line is about tangent to the crown of the upper chord, as 0.33 for half-through arches, and as 0.38 for high-deck structures.

PROBLEM NO 2.

As far as solid-rib arches are concerned, the question of the economic depth of the rib does not arise; because that dimension should always be made as great as a proper consideration of the section for resisting compression will permit. The member acts as both a beam and a strut; hence, if the webs are made thin and of economic depth for the bending, they will not be thick enough to comply with the rules governing the proportioning of built compression members. It is true that rigid adherence to these rules is not always necessary in arch designing, but they should never be transgressed to any great extent.

For braced-rib arches, however, it is practicable to use the economic rib depth. Up to the present time, no rule for determining this has been given. Fortunately, No. 8 of the before mentioned ten equations offers a means for solving the problem. The area of the chords,

$$A_c = \frac{T - \frac{2\,M}{d}}{p_c},$$

is divided into two parts, *viz.*, $A_t = \frac{T}{p_c}$, due to direct thrust, and $A_m = \frac{2\,M}{d\,p_c}$, due to bending from the live load only, provided that the center line of the rib is properly located; in which case the area for the web, $A_w = \frac{2\,S}{p_w}$, is also due to live load only. On that basis the partial weight of the chords, A_m, should equal the weight of the web, in order to obtain the greatest possible economy of metal. After determining the values of A_m and A_w, if they are found to be unequal, the economic depth, d', can be obtained thus:

$$A'_m = A_m \times \frac{d}{d'},$$

$$\text{and } A'_w = A_w \times \frac{d'}{d}.$$

Equating these makes $A_m \frac{d}{d'} = A_w \frac{d'}{d}$, or $d' = d\sqrt{\frac{A_m}{A_w}}$

Replacing A_m and A_w by their values gives:

$$d' = d\sqrt{\frac{\frac{2\,M}{d\,p_c}}{\frac{2\,S}{p_w}}} = d\sqrt{\frac{M\,p_w}{S\,d\,p_c}} \dots\dots\dots\dots\dots\dots \quad (1)$$

After making the calculations to determine the economic ratio of rise to span for each case, the assumed economic rib depth was checked by Equation (1), the results being as shown in Table 2.

TABLE 2.

Span, in feet.	Assumed depth, in feet.	Economic depth, in feet.	Ratio of economic depth to span.
200.................	16	15.48	0.0774
500.................	40	38.65	0.0773
800.................	60	60.24	0.0753

It is evident from Table 2 that the economic depths of braced-rib arches vary from about 7.5 to 7.75% of the span; but no mistake of any importance would be made if they were taken as 7.5% for three-hinged arches of all span lengths. There is no reason for deeming that the economic depth is any different in the case of two-hinged arches; and in hingeless arches it is probable that the economic average depth will be about the same. In spandrel-braced arches, it will suffice to make the arch depth at mid-span equal to from 6 to 8% of the span length; but here esthetics—not economics—should govern.

In two-hinged arches of very great span length, such as the famous Hell Gate Arch Bridge, it is proper to consider the economics involved by varying the arch depth approximately in proportion to the size of the bending moment. Such treatment would place the greatest depth at the haunches or quarter points; and in certain cases of long spans this might be permissible, from the esthetic standpoint, but generally it is not. Crescent-shaped, two-hinged arches are economic in the feature of reducing the rib depth gradually in the outer quarters of the span; but to the untrained eye they suggest an element of weakness. Of course, the real strength is dependent solely on whether sufficient sectional areas of members, with the metal properly disposed, have been provided; but the element of stiffness is certainly not improved by making the ribs shallow—and rigidity is often just as essential as mere strength. Making the rib depth proportional to the bending moment involves uniformity in the chord sections; but this is no important desideratum. In designing arch bridges, esthetics and rigidity should never be sacrificed for the sake of economy in weight of metal, nor for convenience in manufacture.

The before-mentioned tests prove that the economic rib depth is the same for both railway and highway structures, and that it is almost entirely independent of the size of the live load.

In order to indicate the effect on the total weight of metal by varying from the economic rib depth, take the case of the 800-ft. span, in which the assumed depth of 60 ft. was almost exactly correct, and test the increase for other depths. In the railroad structure, taking the values of A_m and A_w equal to 177 sq. in. and assuming various depths, we have the results given in Table 3, from which it is evident that, for the particular span under consideration, a material variation from the economic depth of rib may be made without greatly increasing the weight of metal in the arch. Any variation that is likely to be adopted will be a reduction; because, generally, the appearance of the arch is improved by making its rib depth smaller than the economic one. The reason the percentages in the table do not increase faster with the variation in depth from the most economic is that, for this span, the area of chord section affected by the bending moment is only about one-third of the total area. The writer recognizes that this demonstration is open to criticism, because he has neglected the increase in chord sections due to the augmented dead load; but the amount thereof is immaterial.

TABLE 3.

Assumed depth, in feet.	Ratio of assumed depth to economic depth.	$A_m + A_w$, in square inches.	Corresponding increased percentage of total weight of ribs.
30	0.50	442.5	13.0
35	0.58	406.7	7.7
40	0.67	383.5	4.3
45	0.75	368.7	2.2
50	0.83	359.9	0.9
55	0.92	355.3	0.2
60	1.00	354.0	0.0
65	1.08	355.1	0.2
70	1.17	358.2	0.6
75	1.25	362.9	1.3
80	1.33	368.7	2.2
85	1.42	375.7	3.2
90	1.50	383.5	4.3

The results in Table 3 are shown by diagram in Fig. 6. Although it is true that this diagram was prepared for spans of 800 ft., it can be used, with sufficient accuracy for all practical purposes, in the case of arches of other span lengths, its main purpose being to show about how far in any case it is advisable to depart from the economic rib depth, which, as previously indicated, is 7.5% of the span length.

It might be well to point out that the shorter the span the greater will be the percentage of increase in weight of arch rib, for the same ratio of actual to economic rib depth. For instance, in Table 3, which is for an 800-ft. span, if the depth is made 75% of the economic one, the increase in weight of rib metal will be 2.2%; but, in a 500-ft. span, it would be about 2.4%, and about 2.8% in a 200-ft. span. These figures endorse the statement previously made that it is proper to use the diagram, Fig. 6, for all span lengths.

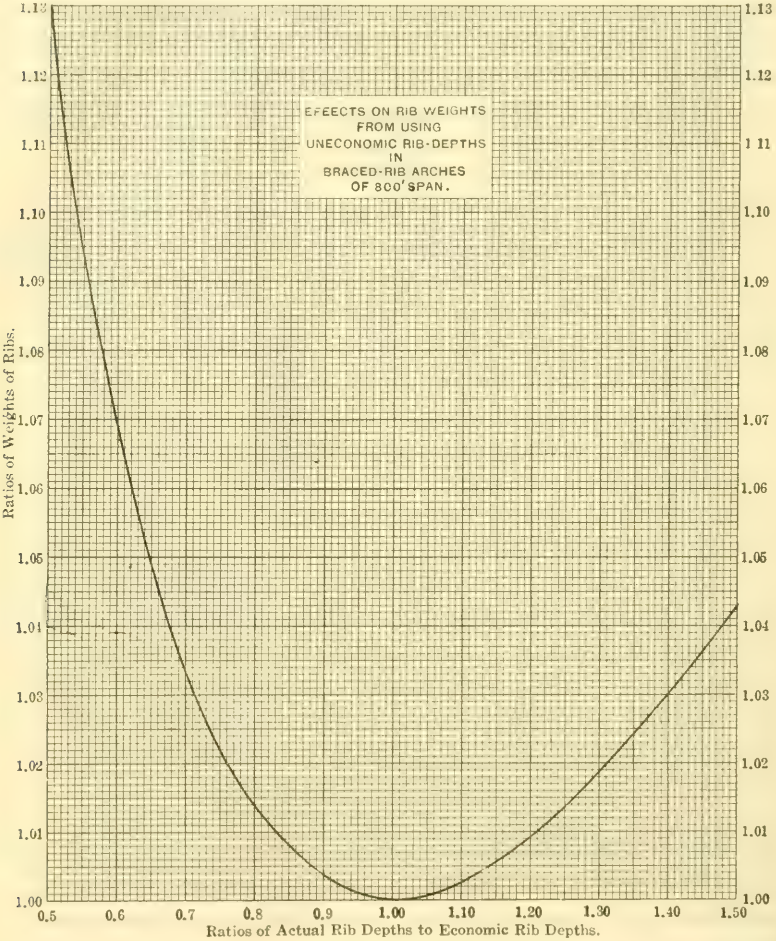


FIG. 6.

PROBLEM NO. 3.

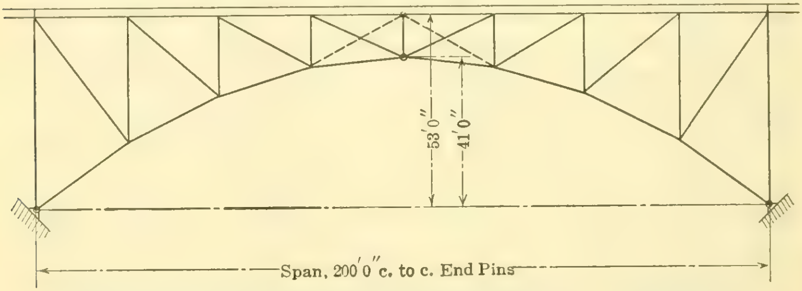
Strictly speaking, a spandrel-braced arch bridge is a structure in which the dead-load thrusts and the full live-load thrusts are carried directly by the bottom chords of the arches, the top chords and the web members serving only to brace the bottom chords under unsymmetrical or partial loading. The spandrel members thus have only a stiffening function to perform, similar to that of the stiffening truss of a suspension bridge—hence the name, "Spandrel-Braced Arch". In accordance with that definition, the crown-hinge in a spandrel-braced arch should, from the theoretical point of view, be in the bottom chord; thus obviating the necessity of the stresses from dead load and full live load traveling through the spandrel members. The simplest and most direct stress path, *viz.,* through the bottom chord, apparently should afford the maximum economy; but, in light bridges, some of the top-chord members may have sections unavoidably large in respect to the theoretical requirements; and in that case the placing of the hinge in the top chord would tend to utilize a certain quantity of idle metal, and, at the same time, reduce the sectional area of a portion of the bottom chord, thus effecting a saving in the total quantity of metal in the structure. In the writer's opinion, this is a legitimate economic expedient; but he is opposed to putting the crown-hinge anywhere except at mid-depth of rib in the case of both solid-rib and braced-rib arches. The object of this last suggested arrangement is to divide the thrust equally between the upper and lower chords of the rib; then, by keeping the center line of the latter as nearly as may be on the arc of a parabola, the chord stresses due to direct thrust will tend to divide themselves equally between the two chords, provided, of course, that the dead load is uniformly distributed. The curve of the bottom chord of a spandrel-braced arch, passing through the three hinges, should be a parabola, if the dead load is practically uniform across the span; otherwise, this curve should correspond to the equilibrium polygon for

$$\text{D. L.} + \tfrac{1}{2}\ (\text{L. L.})$$

covering the whole span.

In order to settle this question of the best location of the crown-hinge in the spandrel-braced arch, and at the same time to compare the weights of spandrel-braced arches with those of the corresponding solid-rib and braced-rib arches, two designs have been made for a

200-ft. span, spandrel-braced, steam railway, arch bridge, having the same vertical distance between top-chord and springing points as in the other two cases, as well as the same panel length and the same live load. For the purpose of avoiding the adoption of an uneconomic ratio of rise to span length, the arch depth was reduced to 12 ft. at the crown. With a depth of 53 ft. at the springing points, this provides a neat layout, as shown in Fig. 7; and the ratio of rise to span, measured on the bottom chord, is 0.2, which is about the inferior limit of the economic range. With the crown-hinge in the top chord, the ratio of rise to span length is 0.265, which is a trifle above the superior limit of the said range. These two layouts give a fair comparison between the structure with the bottom-chord crown-hinge and that with the top-chord crown-hinge. In this case there is no need of including the weights of the lateral systems in the comparison, as they are the same for each structure. The results of the calculations show that the weights of metal per linear foot of span per side (for arches only) are 1 182 lb. with the hinge in the bottom chord and 1 146 lb. with the hinge in the top chord. Contrary to what might be anticipated from purely theoretical considerations, placing the hinge in the top chord produces a less total weight of arch metal than placing it in the bottom chord, the difference in this case being about 3 per cent. A study of the two diagrams of stresses and sections shows that this result is due primarily to the effect of reversing stresses. Had the latter been ignored, the economics would have been reversed, and the difference would then have been 5% in favor of the location in the bottom chord. The provision for reversal of stresses is respon-



LAYOUT FOR A 200-FOOT, SPANDREL-BRACED, STEAM RAILWAY, ARCH BRIDGE.
(Dotted lines represent reversed position of the diagonals at the crown when the hinge is located in the top chord.)

FIG. 7.

sible for 10% of the total weight of metal with the hinge in the bottom chord, and for only 2% thereof with the hinge in the top chord.

In the solution of Problem No. 7, it became necessary to compute the weight of metal for a 500-ft., spandrel-braced, three-hinged arch; and advantage was taken of this to find the effect on the total weight of arch metal by placing the crown-hinge first in the top chord and then in the bottom chord. The ratio of weights of metal proved to be 1.04, the economics being in favor of the higher hinge.

These results agree in kind, but not in amount, with the subsequently mentioned findings of Merriman and Jacoby in their investigation of the economics of the Niagara Arch Bridge. It may be finally concluded, therefore, that in spandrel-braced, three-hinged arches the economic location of the crown-hinge is in the upper chord.

Problem No. 4.

In determining the ratios of weights of metal required for the solid-rib, the braced-rib, and the spandrel-braced types, it was thought at first that it would suffice to test for the 200-ft. span only, and to make the assumption that what holds true for that length will hold also with sufficient exactness for all other span lengths; but, later, it was necessary to compare some longer spans. The weights of the arches with the superimposed columns and their bracing have already been determined for the solid-rib and the braced-rib types; and two spandrel-braced, steam-railway, arch bridges, of the same live-load carrying capacity and having the same vertical distance between grade and springing points, have been designed, and their weights of metal have been computed. From these weights and by using certain data in the writer's latest published work on bridges, there have been computed the weights of metal per linear foot of span per side in the 200-ft. arches and the corresponding lateral system, *viz.*, 1 146 and 204 lb., respectively, making a total of 1 350 lb.

From this and other weights previously found we have the data in Table 4.

TABLE 4.

Type of arch structure (200-ft. span.)	Total weight of metal, in pounds per linear foot per side, for ribs and lateral system.
Solid-rib	1 950
Braced-rib	1 490
Spandrel-braced	1 350

Had the weight of metal in the floor system and that on piers been included in each case, we should have had the weights given in Table 5.

TABLE 5.

Type of arch structure (200-ft. span.)	Total weight of metal, in pounds per linear foot of structure, including metal on piers.
Solid-rib	5 500
Braced-rib	4 580
Spandrel-braced	4 330

From Table 5 it is evident that, even with a somewhat lower pound price of metal for plate-girder structures, the braced-rib type for railroad bridges of 200-ft. span is more economical than the solid-rib type; and the divergence of cost between them will augment as the span increases. It is probable that it will diminish somewhat for spans down to 100 ft. (at which length simple, plate-girder spans would be preferable); but it is not likely that, for railroad structures, the solid-rib type will in any case be quite as economical as the braced-rib type.

In making the calculations for Problem No. 7, as previously stated, it became necessary to compute the weight of metal for a 500-ft., spandrel-braced, three-hinged arch; and by a little extra computation it was practicable to compare the total weights of metal in braced-rib and spandrel-braced arch bridges for double-track, steam-railway structures of that span; but it was necessary to include the floor metal, because of the longer panels in the spandrel-braced structure. The latter required about 7% more metal than the braced-rib structure; but a revised set of computations, with more nearly equal panel-lengths, would probably have reduced that difference somewhat, although it certainly could not have lowered it more than 2 or 3% of the total weight per foot.

Concerning the economics of the spandrel-braced arch, as compared with the braced-rib structure, it appears, therefore, that it is a little lighter for the 200-ft. span and a little heavier for the 500-ft. span; but, if the arch is to be erected by cantilevering, the saving in weight of erection metal will nearly always make the spandrel-braced structure the more economical.

Problem No. 5.

Up to the present time, the comparative economics of hingeless, two-hinged, and three-hinged arches have been absolutely undetermined, as is shown by the diametrically opposed views of a number of engineering writers. Merriman and Jacoby claim that, in their analysis of the two-hinged, spandrel-braced, arch bridge at Niagara, they found a saving of main sections amounting to 0.8% by the use of a crown-hinge in the lower chord, one of 8.8% by placing it midway between the chords, and one of 11.8% by putting it in the upper chord. Again, the late F. C. Kunz, M. Am. Soc. C. E., a high authority on bridges, in a letter to the writer, gave two formulas for weights of metal in two-hinged arches and their lateral bracing, and stated that for three-hinged arches such weights may be reduced 15 per cent.

On the other hand, Malverd A. Howe, M. Am. Soc. C. E., found, for a 416-ft. arch bridge, having a 67-ft. rise, the following relative weights of metal:

Hingeless type	1.00
Two-hinged type	1.21
Three-hinged type	1.30

Joseph W. Balet claims* that there is no difference in the economics of the two-hinged and three-hinged arches, but that the hingeless type is more economical than either.

Again, Willis Whited, M. Am. Soc. C. E., is quoted† as stating that "an arch without hinges, or with only two hinges at the ends, has less material and looks better than a three-hinged arch".

From the preceding it would appear that there is a strikingly great uncertainty about the economic effect of the hinging of arches; and, in consequence thereof, the writer has prepared diagrams of stresses and sections for 500-ft. arch bridges, first, for the three-hinged type to carry the steam-railway load hereinbefore specified, then a similar structure to carry the highway and electric-railway loadings, also previously indicated; second, for the corresponding two-hinged type of structure with both loadings; and, third, for the corresponding hingeless type of structure, also with both loadings.

In order to save time, the intensity for chord members was assumed for all cases to be 14 000 and that for web members 12 000 lb. The former intensity is for compression only (for which kind of stress the chords were always proportioned); but the latter intensity applies to both tension and compression, because it allows about the right amount for area lost by rivet holes, and conforms for web members in compression quite accurately with the formula,

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* "Analysis of Elastic Arches."

† In Tyrrell's "History of Bridge Engineering."

$$C = 16\,000 - 60\,\frac{l}{r}.$$

After all the diagrams of sections were completed, the correctness of these assumed intensities was checked, and the results were found to be exceedingly close, the average error for all six designs being only 1%, and the maxima 4% on the side of safety and 2% on the side of danger. Moreover, these variations affected the various types about alike, hence the approximate assumptions do not tend toward any unfairness in the comparison of weights.

There was another short cut made that involves a slight error in the total weight of web metal; but it affects all cases to the same extent. It is the use of a single value of impact for all the truss members of the span, instead of varying it for each web member according to the length of span covered by the moving load when the said member receives its greatest stress.

The weights of the main members in all six cases were computed, and the details were properly allowed for by percentage, due cognizance being taken of the weights of the special details at the hinges and of those at the anchorages. In the hingeless and the two-hinged types the temperature stresses were computed for a variation of 60° Fahr. above and 60° below normal; but when temperature stresses were added to those due to live load, impact, and dead load, the intensities of working stresses were increased by 20 per cent. As the spandrel columns and their bracing would average in length about the same for all three types, the weights of these parts of the structure were not considered, and only those of the arch-ribs were compared.

It was found that the economics of the three types depend mainly on two important features of the designing specifications, *viz.*, the method of treating reversing stresses, and the importance accorded to temperature stresses. If the effect of stress reversion is entirely ignored, the hingeless and the two-hinged structures will be lighter than the three-hinged one; but if each section on which there is reversion is computed for the greater stress plus 50% of the smaller one, which is in conformity with many of the best modern bridge specifications, there is only a small advantage in favor of the two-hinged type over the three-hinged. Probably, if the percentage were 75, instead of 50, as some engineers specify, the weights would be alike for the two types.

If temperature stresses are entirely ignored, the two-hinged type will have an advantage of about 7% over the three-hinged type; but if they are provided for without augmenting the intensities of the working stresses, there will be a 7% advantage for the three-hinged type. If the intensities for the combination of the stresses due to all the loadings and the temperature effects are increased 20% above normal, there is an advantage for the two-hinged type of 5% or more. Probably, if the increase of intensity above normal were 10% instead of 20, the weights of metal for the two types would be about equal. As it is logical to allow a 20% increase of intensities for the combination, it is evident that, for 500-ft. spans, the two-hinged type, as far as weight of metal is concerned, has the advantage over the three-hinged. The exact figures for the comparison are as given in Table 6.

TABLE 6.

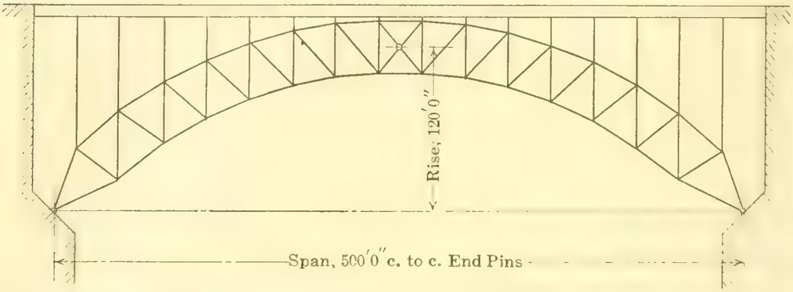
Character of structure.	Number of hinges.	Weight of metal, in pounds per linear foot per side.	Comparative percentage.
Railway...............	3	2 180	100
Railway...............	2	2 075	95
Railway...............	0	2 295	105
Highway..............	3	1 230	100
Highway..............	2	1 134	92
Highway..............	0	1 250	102

In the comparison in Table 6 the effects of wind loads have been ignored, for two reasons: first, because it is probable that they would be so small as to have no influence on the sections after allowing the usual 30% excess for the intensities of working stresses; and, second, because any small variations they might involve would be practically of like kind and amount for all cases.

Fig. 8 is the layout for the three-hinged and two-hinged arches of 500-ft. span, and Fig. 9 is that for the corresponding hingeless structure.

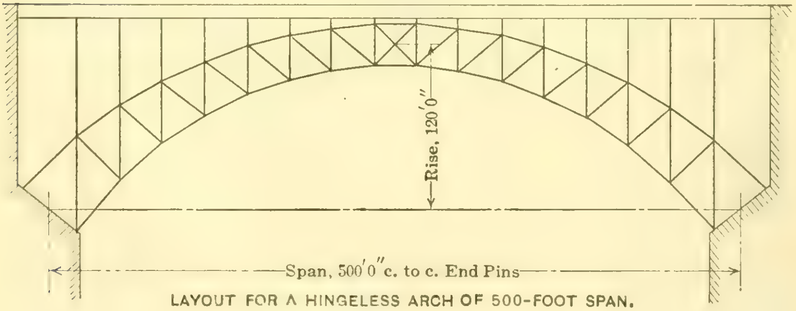
It might be well to call attention to the fact that in retaining the same outline for the ribs of the 500-ft., two-hinged arch as adopted for the corresponding three-hinged structure, a slight injustice has been done to the former type, because its approximately economic shape is that of a crescent; but the difference in weight involved by this variation from the ideal is small. The reason for ignoring it is the saving in labor involved in making computations by assuming the two outlines to be identical.

Again, it is possible that the layout for the hingeless type is not the most economical one that can be drawn; but it is thought to be so close to it as not to affect the economic comparison materially. A small quantity of metal might have been saved by adopting an outline somewhat like that which Gustav Lindenthal, M. Am. Soc. C. E., for motives of esthetics and of suitability to meet existing conditions, but assuredly not for those of economy in weight of metal, used for his two-hinged Hell Gate Arch Bridge. The rib outlines of that long span are, generally speaking, economically appropriate for a hingeless arch, but not for one with hinges at the springing points.



LAYOUT FOR THREE-HINGED AND TWO-HINGED ARCHES OF 500-FOOT SPAN.
(In the three-hinged arch the chords in the middle panel are false members)

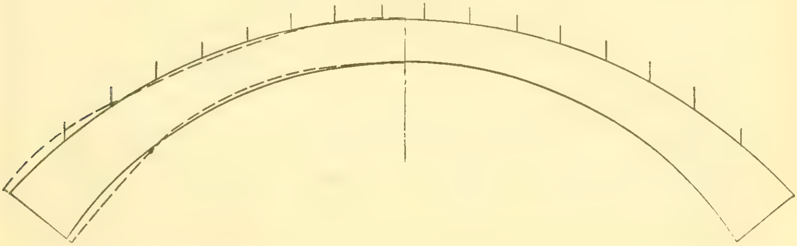
FIG. 8.



LAYOUT FOR A HINGELESS ARCH OF 500-FOOT SPAN.

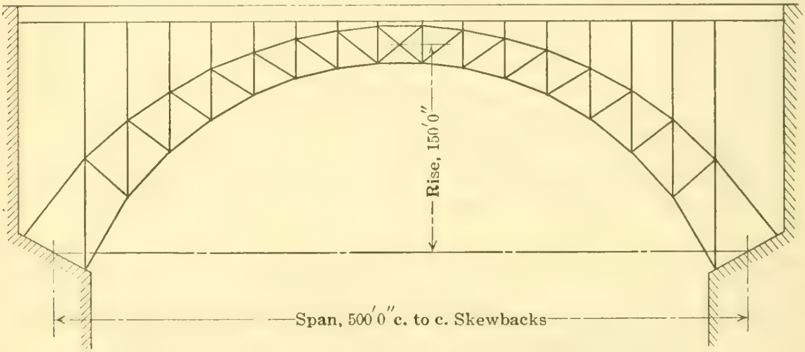
FIG. 9.

As an approximate test of the correctness of the assumed outline for the 500-ft., hingeless, arch span, find the average of the rib depths at all the panel points and call the result d_a; then compute the average of all the proportioning bending moments at these panel points, and call the result M_a. If M is the proportioning bending moment at any panel point (that is, the larger moment plus one-half of the smaller moment of the opposite sign), find the ratio, r, of $\frac{M}{M_a}$ for each panel point, and multiply it by d_a, then lay out the resulting depth symmetrically above and below the center line of the arch, and join the points thus determined, so as to form new chord center lines. This has been done, as shown in Fig. 10, from which it will be seen that, for five and a half panels on each side of the crown, the curve was drawn just about right, but for the remaining three panels the rib depth should have been greater. As it is not absolutely essential that the rib depth at all points be exactly proportional to the adjusted bending moment, it will suffice to adopt a certain depth at the ends and about half as much at the crown, and run in approximately parabolic curves accordingly.



LAYOUT FOR A HINGELESS ARCH OF 500 FEET SPAN, SHOWING MODIFICATION FOR DEPTHS PROPORTIONATE TO ADJUSTED BENDING MOMENTS.
(Solid lines represent original outline as adopted for design, and dotted lines represent modified ideal outline.)
FIG. 10.

From Table 6 it seemed likely that, for 500-ft. spans, there is no economy in the hingeless arch as compared with arches having either two or three hinges. However, it was deemed possible that a greater rise might reduce the temperature stresses so as to lower materially the total weight of metal in the hingeless arch. A rough test of this point was made by assuming the rise of the 500-ft. arch to be increased 30 ft., or from 0.24 to 0.30 of the span length, with the result that the weight of metal was reduced about 7.5% by diminishing the prejudicial effect of the temperature stresses, but was increased about 7% by reason of the greater length of the arch rib, leaving the possibility of some economy by the reduction of stresses from live and dead loads. It was then decided to make an exact determination of the effect of the increased rise, on the layout shown in Fig. 11, even at the expense of 3 days' work for a computer, by making a complete determination of stresses and sections and estimating therefrom the weight of metal. From this it was ascertained that for the arch alone the saving effected amounted to 6%; but, when the proper addition was made for the superimposed columns and their bracing, the gain was exactly exhausted by the increased height from springing point to grade.



LAYOUT FOR A HINGELESS ARCH WITH A RATIO OF RISE TO SPAN OF 0.3

FIG. 11.

It was evident, though, that if the rise of 150 ft. was fixed for the 500-ft. span, the hingeless arch might possibly prove more economical than the three-hinged one; hence, a comparison was made, with the result of a difference of one-half of 1% in favor of the three-hinged type.

The combined highway and electric railway, hingeless arch, with 150 ft. of rise, was also computed, but the saving in the arch alone, as compared with the corresponding span of 120 ft. rise, was only 3%, which was not enough to offset the increase in the weight of spandrel columns and their bracing.

From the four designs (railway and highway) for the 500-ft. span, hingeless arches, there can be drawn a deduction of some value, *viz.*, the manner in which the economics of structures of that type, as compared with three-hinged arches, vary with the ratio of live load plus impact to total load. In the case of the railroad structure, that ratio is 0.645; and in that of the highway structure it is 0.351. In Fig. 12 the abscissas represent the ratios of live load plus impact to total load, and the ordinates indicate the ratios of weights of metal in hingeless arches to the weights in corresponding three-hinged structures. The right line on the diagram was plotted solely by the two ratios thus determined; and it is assumed to apply properly for all

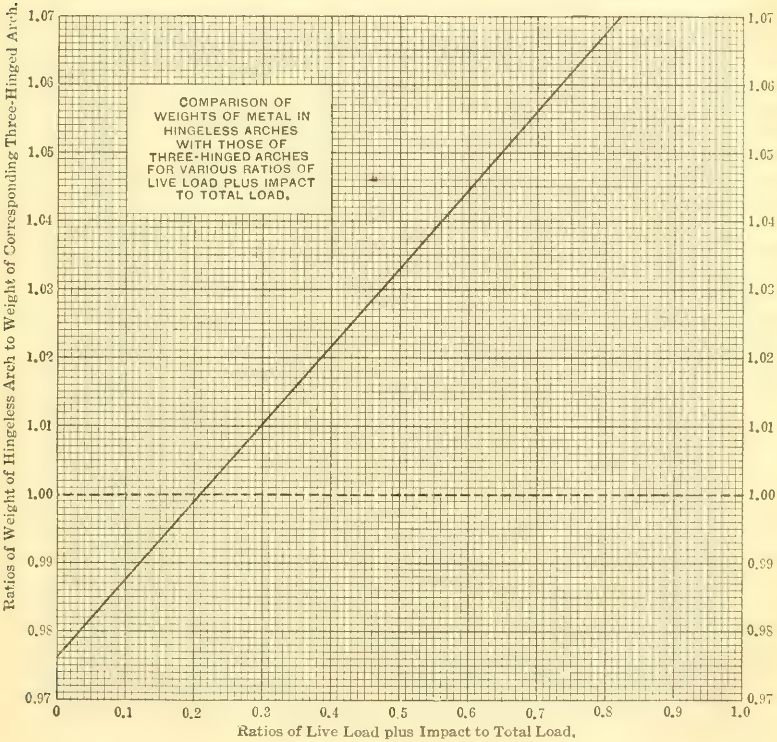


FIG. 12.

spans and loadings, for the following reason: The sole cause of the variation of the economics in the two 500-ft. span, hingeless arches is the factor of the ratio of live load plus impact to total load. Hence, if we know, for several widely divergent span lengths, the ratios of live load plus impact to total load (as can readily be determined for any feasible span by the use of the ten equations previously mentioned, and the numerous diagrams of weights of metal per linear foot of span)* we can determine, for steam-railway bridges, and for the type of combined highway and electric-railway bridges herein adopted as standard, the economics of hingeless and three-hinged arches. This has been done; and the results have been plotted in Fig. 13, in which the abscissas represent span lengths for arch bridges up to a limit of 1 000 ft., and the ordinates indicate the ratios of weights of metal in

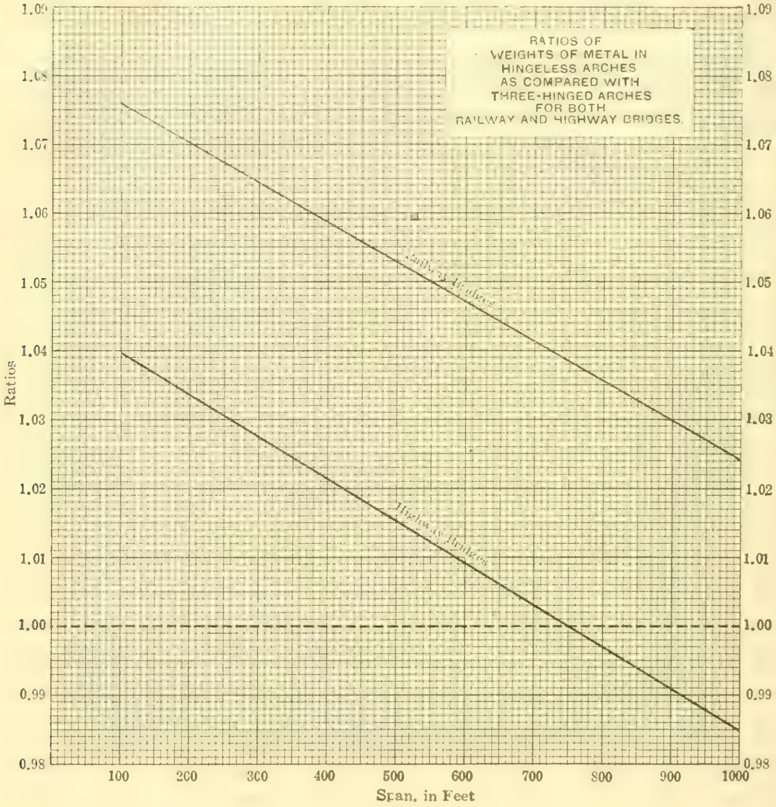


FIG. 13.

hingeless arches as compared with those of the corresponding three-hinged structures. Although the upper line of the diagram was plotted from data obtained for double-track bridges, no error of any magnitude will be made by assuming that it holds good for all strictly railway structures; and the lower line may be used safely for all modern highway bridges with paved floors supported by reinforced concrete bases and having concrete sidewalks.

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* Given in Chapter LV of "Bridge Engineering".

Based on the numerous weight computations made specially for the preparation of this paper, the following formulas for weights of metal in the arches alone, per linear foot of span, in arch bridges of the several types, have been established:

For Three-Hinged Arches.—

$$W_a = (0.000282\ D + 0.000426\ L)\ l \dots\dots\dots\dots (2)$$

For Two-Hinged Arches.—

$$W_a = (0.000248\ D + 0.000416\ L)\ l \dots\dots\dots\dots (3)$$

For Combined Two-Hinged and Three-Hinged Arches.—

$$W_a = (0.000282\ D + 0.000416\ L)\ l \dots\dots\dots\dots (4)$$

For Hingeless Arches.—

$$W_a = (0.000272\ D + 0.000460\ L)\ l \dots\dots\dots\dots (5)$$

These four formulas are based on the writer's published designing specifications, which treat reversing stresses by adding one-half of the smaller stress to the larger stress and proportioning for the sum; but if the effect of reversion is entirely ignored, as some engineers deem proper, these formulas will reduce to the following:

For Three-Hinged Arches.—

$$W'_a = (0.000292\ D + 0.000396\ L)\ l \dots\dots\dots\dots (6)$$

For Two-Hinged Arches.—

$$W'_a = (0.000258\ D + 0.000380\ L)\ l \dots\dots\dots\dots (7)$$

For Combined Two-Hinged and Three-Hinged Arches.—

$$W'_a = (0.000292\ D + 0.000380\ L)\ l \dots\dots\dots\dots (8)$$

For Hingeless Arches.—

$$W'_a = (0.000270\ D + 0.000398\ L)\ l \dots\dots\dots\dots (9)$$

In Equations (2) to (9), inclusive, W_a, or W'_a, is the weight of metal, in pounds per linear foot of span, in the arches of the structure; D is the dead load, in pounds per linear foot of span; L is the live load plus impact, in pounds per linear foot, used in making the calculations; and l is the span length, in feet. These eight equations will give fairly accurate results (slightly on the side of safety) for ordinary conditions which do not vary greatly from the theoretically economic ones.

In computing the value of L for insertion in Equations (2) to (9), inclusive, the equivalent uniform live load and the impact should be determined for the half-span length, as herein previously indicated.

In order to show that the writer's past surmises concerning the economics of the hingeless type of arch were not far wrong, he takes the liberty of quoting the following:*

"It is claimed that hingeless arches require less metal than any other type; but the author, upon general principles only, is inclined to disagree with that opinion. He has never had occasion to design an arch without hinges, but feels quite confident that if he should ever figure one, he would find that a proper provision for excessive temperature stresses, possible large indeterminate stresses, unusual detailing, heavy anchor-bolts, and an inherent sense of fitness in proportioning sections, would so increase the weight of metal as to absorb all of the theoretical economy over the three-hinged arch involved by the smaller average direct stresses as shown on the stress sheets."

Problem No. 6.

From the calculations for the two-hinged and three-hinged types, it was easy to compute the stresses and sections for a combination of the two, making the structures three-hinged for the dead loads and two-hinged for the live loads. The results showed, as was anticipated by *a priori* reasoning, that the combination produces weights of metal intermediate between those of the two types previously computed. The exact results are given in Table 7.

TABLE 7.

Character of structure.	Weight of metal, in pounds per linear foot per side.	Percentage compared with three-hinged structure.
Railway arch..................	2 108	97
Highway arch..................	1 212	99

From Tables 7 and 6, it will be seen that there is an increase of weight of 2% for the railway structure and of 7% for the highway structure in the combination, as compared with the two-hinged type; but the resultant excess of cost will generally be considered of small importance in comparison with the value of the certainty of the dead-load distribution effected by the hinging, combined with a reduction in the difficulty and expense of erection.

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* From p. 621 of "Bridge Engineering."

As compared with the three-hinged arch, the combination type affords greater rigidity under moving load—an especially important feature in railroad bridges. Again, the erection problems are less difficult, and therefore less expensive, for three-hinged than for two-hinged arch structures.

Problem No. 7.

The solution of the problem of determining the economics of the cantilever-arch bridge was accomplished thus:

First.—A design was made for a three-hinged, spandrel-braced, double-track railway, arch bridge of 500-ft. span and of approximately economic rise; and the weight of metal for the arches thereof was then computed.

Second.—Simple-truss flanking spans, each 292 ft. long, were added, resting at their outer ends on rollers, and attached at their inner ends to the vertical end-posts of the arches; and the weight of metal for these flanking spans was calculated.

Third.—It was assumed that the arches were cantilevered out for three of the seven panels, and that the remaining four panels formed the suspended span; then the weights of both the arch span and the flanking spans were computed. This layout was deemed in advance by the writer to be the most economic one possible.

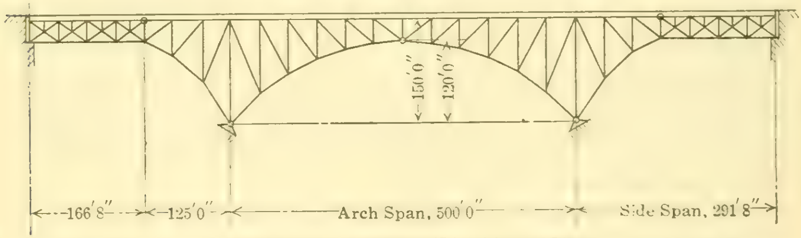
Fourth.—Next, the number of panels in each cantilever arm was reduced to two; and, as before, the weights of metal in all spans were calculated.

Fifth.—Finally, the number of panels per cantilever arm was increased to four, and the work of computation was repeated.

As surmised, there was quite an economy of metal by cantilevering, and the three-panel, cantilever arms proved to be the most economical, the saving of metal in the arches and trusses combined being about 11 per cent. There was a small increase, instead of a reduction, of weight of metal in the arch, but the economy in the flanking spans was quite marked. The best lengths of cantilever arm and suspended span were, respectively, about 40 and 60% of the total length of one flanking span. The layouts for two of these computed structures are shown in Figs. 14 and 15, the former being for the cantilever arch, and the latter for an ordinary arch with flanking simple-truss spans.

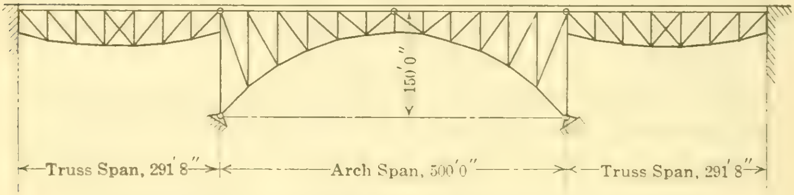
It was thought possible that a different length of flanking span would entail different results; hence, the length was reduced to 208 ft., and the calculations were repeated. As in the last case, there was a saving in the combined weights of arches and trusses, but not so pronounced an economy as before; however, the economic ratios for cantilever arm and suspended span to total length of flanking span remained unchanged, being, respectively, about 0.4 and 0.6.

It was for convenience of computation that the arches in these comparisons were made three-hinged; but, it is evident, after giving the question a little thought, that the conclusions reached would have been practically the same had the arches been two-hinged. Hingeless arches, of course, are not suitable for the cantilevering of flanking spans.



LAYOUT FOR A CANTILEVER ARCH BRIDGE.

FIG. 14.



LAYOUT FOR AN ARCH BRIDGE, WITH FLANKING SIMPLE-TRUSS SPANS.

FIG. 15.

PROBLEM No. 8.

A few years ago the writer made an attempt to obtain, by correspondence with a large number of bridge engineers, some reliable data relating to the ratios of weights of metal in arch bridges and truss bridges of the same span length and the same live-load carrying capacity; but he was unsuccessful, as nothing reliable on the subject was known to the Engineering Profession. However, from the numerous calculations made for this paper, combined with weights of simple-truss spans previously published by the writer, there has been prepared the diagram, Fig. 16.

The right lines plotted thereon coincide with those recorded by the following equations:

For Steam-Railway Structures.—

$$P = 106 - 0.08\ S \ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

For Electric-Railway Structures.—

$$P = 93 - 0.07\ S \ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

For Highway Structures.—

$$P = 80 - 0.056\ S \ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

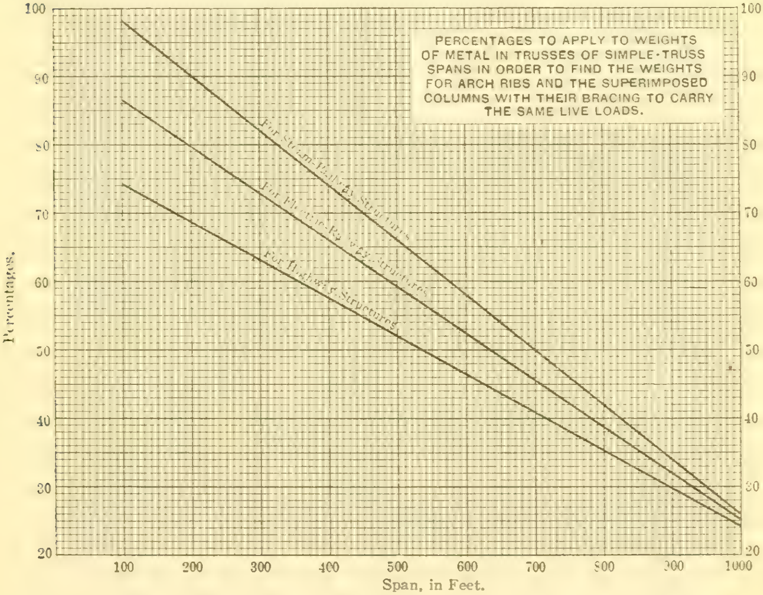


FIG. 16.

In these equations, S is the span-length, in feet; and P is the percentage to apply to the weight of metal in the trusses of any simple-truss bridge, in order to ascertain the weights of corresponding arches and the superimposed columns with their bracing. It must not be forgotten that the superior limit of S in these two equations is about 1 000 ft., which is as far as the recorded weights of simple-truss spans are carried, and that the inferior limit is 100 ft. The two exterior lines of the diagram were computed, but the middle one was interpolated by judgment. None of them can be considered as strictly accurate for all cases, because of the influence of varying conditions precedent.

From Fig. 16 and Equations (10) and (12) it is evident that the arch is more economical for combined highway and electric-railway bridges than for steam-railway structures. This is because of the smaller ratio of live load plus impact to total load in the former. The larger the dead load of the flooring and floor system, the more advantageous is it for the arch structure in comparison with the truss bridge. In the double-track, steam-railway bridges of this investigation, the floor weight per linear foot of span is about 2 200 lb., and in the 60-ft. wide, highway and electric-railway bridge thereof, with its paved floor,

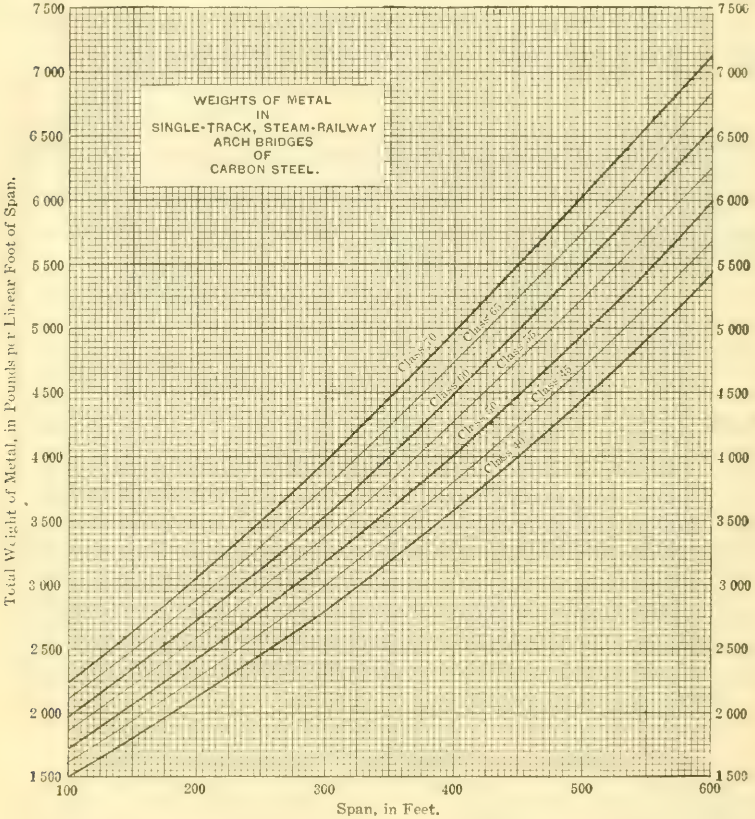


Fig. 17.

reinforced concrete base, and reinforced concrete sidewalks, it is about 6 400 lb. In Fig. 16 the converging of the three right lines as the span length increases is due to the augmenting influence of the dead load.

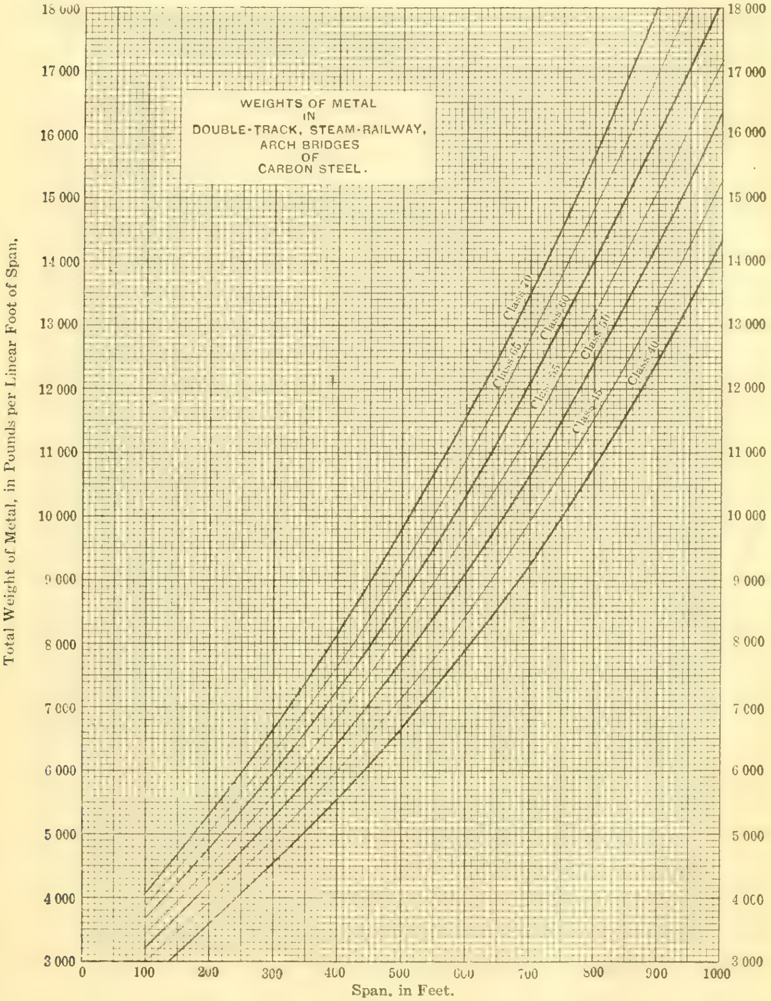


FIG. 18.

No comparison has been made between the weights of solid-rib arches and those of the corresponding truss spans, because such a comparison would seldom be of any use.

By using the percentages shown in Fig. 16 and certain diagrams of weights of metal previously published by the writer, there have been prepared the diagrams of total weights of metal per linear foot of span for three-hinged, braced-rib, arch bridges, shown in Figs. 17, 18, and 19. These are, respectively, for single-track, steam-railway bridges; double-track, steam-railway bridges; and combined highway and electric-railway bridges, with paved floor, reinforced concrete base, and reinforced concrete sidewalks. In preparing these diagrams, due account has been taken of the splaying of the columns in the bents carrying the floor. If these diagrams are to be used for spandrel-braced arches by making a small percentage reduction or addition, based on the deduc-

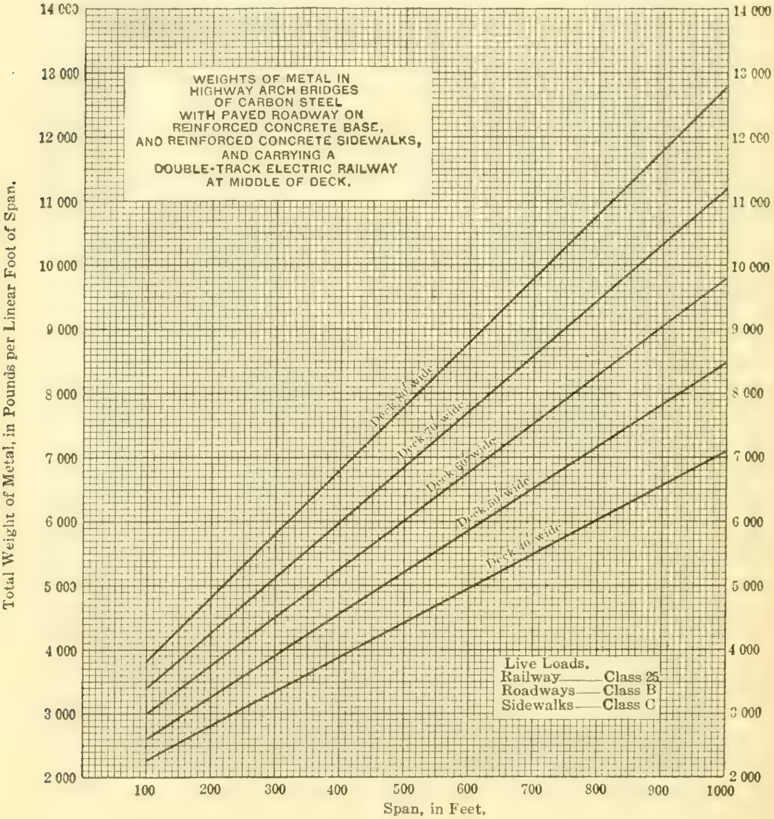


FIG. 19.

tions in Problem No. 4, it will be necessary to multiply the result thus found by the secant of the angle which the splayed spandrels make with the vertical. In order to determine the proper splay for any case, one should remember that the width of structure at the springing should never be less than 30% of the vertical distance from the springing point to grade, and, preferably, not less than 35% thereof.

For weights of metal in multiple-track, arch structures, no error of any importance will be made by assuming them to be directly proportional to the number of tracks (using the double-track records of Fig. 18 as a basis); and for strictly highway arch structures of similar construction throughout, by taking them proportional to the out-to-out width of the deck. In Fig. 19 this proportionality does not hold, because the structures therein diagrammed carry at mid-deck a double-track, electric railway.

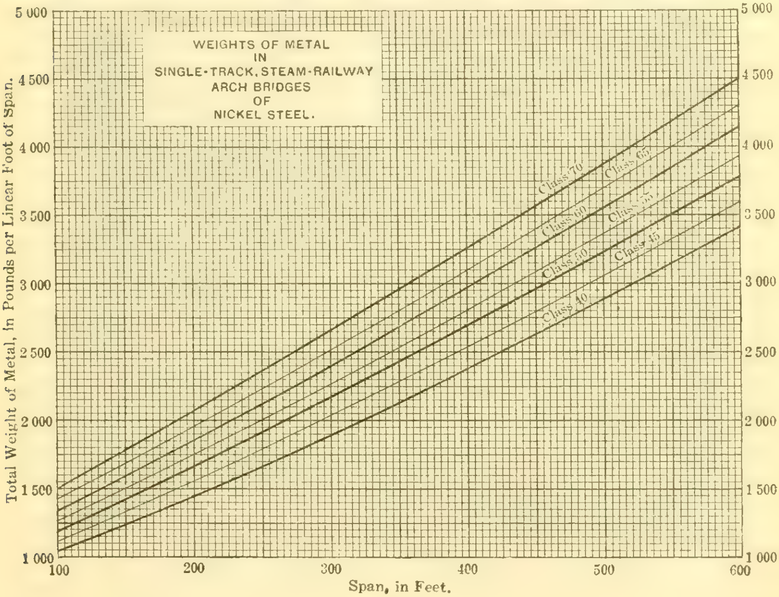


FIG. 20.

It seems hardly necessary to state that for hingeless, two-hinged, and combined three-hinged and two-hinged arches, the total weights of metal per linear foot of span may be readily obtained by applying to the weights, found from Figs. 17, 18, and 19, the small percentage corrections for arch weights hereinbefore determined in the discussion of the economics of the different types, using Equation (2) for finding these arch weights.

It may be of interest to some engineers to know the weights of metal in steam-railway, arch bridges built of nickel steel; consequently, the diagrams, Figs. 20 and 21, have been prepared for single-track and double-track, arch structures, respectively. It seems hardly worth while, however, to give diagrams for highway, arch bridges of nickel steel, because of the uncertainty as to the extent to which the alloy would be used in any particular structure. For bridges of comparatively short span lengths, it might be economical to use it in the arches only; in long spans, in which the importance of reducing the dead load is paramount, it would pay to use it in the floor system also; but in very few cases is it ever advisable to adopt the alloy for the lateral system, on account of the fact that the proper minima sections of

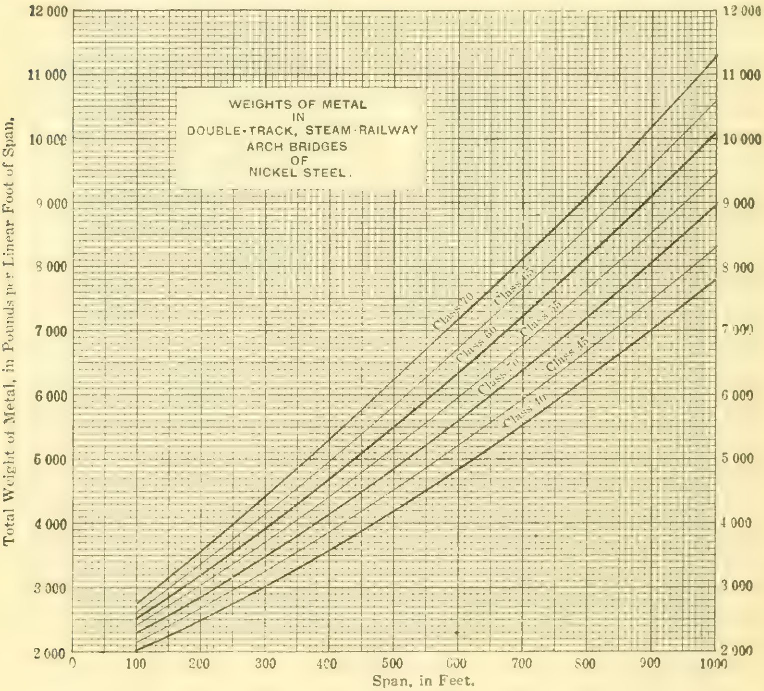


FIG. 21.

carbon steel generally provide an excess of strength for the computed wind stresses.

From the formulas herein given for weights of arch ribs, some interesting deductions may be drawn. For instance, in Equation (2), *viz.*,

$$W_a = (0.000282\ D + 0.000426\ L)\ l,$$

the dead load, D, is composed of the rib weight, W_a, plus the weight of floor, columns, lateral system, etc., all of which may be grouped under the symbol, W', making the equation

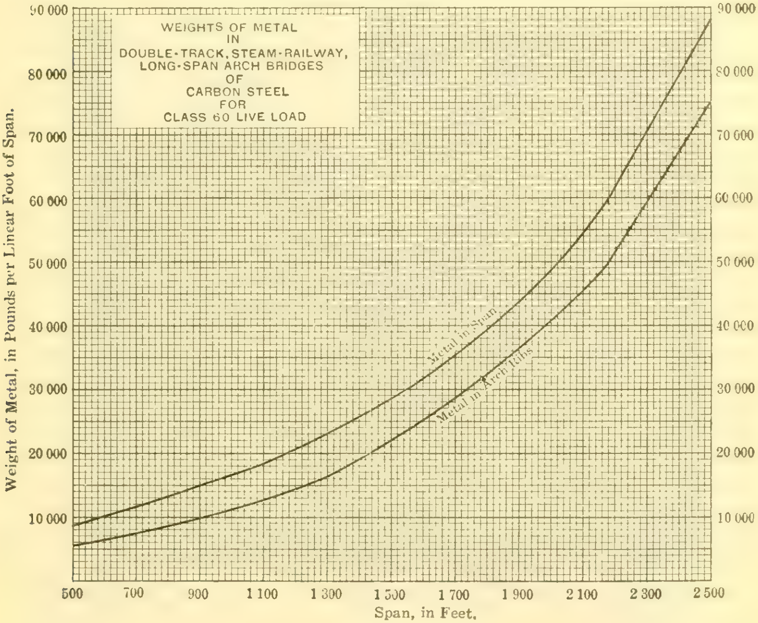


FIG. 22.

$$W_a = (0.000282\ W_a + 0.000282\ W' + 0.000426\ L)\ l.$$

Solving this gives:

$$W_a = \frac{(0.000282\ W' + 0.000426\ L)\ l}{1 - 0.000282\ l}.$$

In order that W_a may be infinitely great, the divisor of the second term must be equal to zero, or

$$l = \frac{1}{0.000282} = 3\,540 \text{ ft.}$$

This is the theoretical limiting span for three-hinged arches of carbon steel, or the span at which such an arch could carry nothing but its own weight without being over-stressed. It will be noted that this limiting length is the reciprocal of the dead-load coefficient in Equation (2), and that a vertical line on the diagram of arch rib weights per linear foot of span, drawn through the abscissa point which represents this value of l, will be asymptotic to the weight curve.

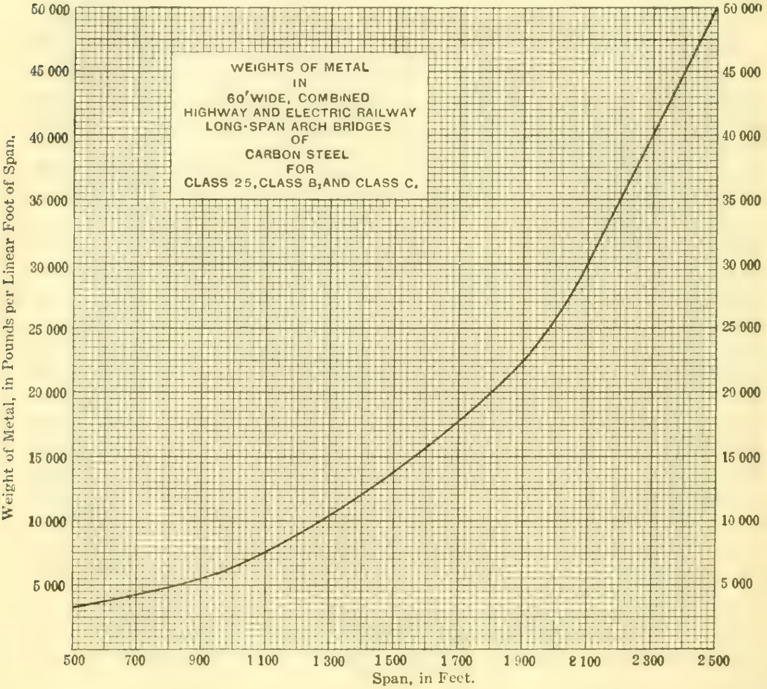


FIG. 23.

Such weight curves for long spans are partly shown in Figs. 22 and 23, the former being for double-track, steam-railway bridges of Class-60 live load, and the latter for the combined highway and electric-railway, 60-ft. wide bridges adopted herein as a standard for ordinary modern highway structures.

From these curves it is possible to determine the economic or practicable limit for arch spans, by assuming, as the writer did years ago, in his economic investigations for cantilevers, that the said limit is reached when it takes 4½ lb. of metal to carry 1 lb. of live load. On that basis, and assuming that the equivalent uniform live load per linear foot for a long span is equal to the car load per linear foot, the limiting weight of metal per foot for carbon-steel, double-track, steam-railway bridges of Class 60 would be 4.5 × 12 000 = 54 000 lb. Referring to Fig. 22, it is found that the span for that weight is nearly 2 100 ft.; consequently, generally speaking, it may be stated that, for steam-railway, arch bridges of carbon steel, the limiting length of span is about 2 000 ft., or the same as the limiting length of main opening in cantilever bridges built of the same material. Judging by analogy, the corresponding practicable limiting length of nickel-steel arch spans is about 2 600 ft.

The various formulas and diagrams in this paper are to be considered as merely approximate; and though they are sufficiently accurate for preliminary estimates and for obtaining trial dead loads, they should not be used by contractors in tendering on work. The reason for this uncertainty is that the varying physical conditions at different crossings affect the arch layouts to such an extent as materially to influence the weight of metal required. As the formulas were based on economic functions, the weights given by their use might very properly be considered as the minima possible; and any uneconomic conditions which may exist will involve an increase thereof, the amount being a matter to be determined by the computer's judgment.

Résumé of Results.

The following is a condensed statement of the principal findings from all the preceding investigations, recorded in the previously indicated order of the problems set for solution:

First.—For three-hinged arches with the grade line approximately tangent to the top chord of the arch at the crown, the average economic ratios of rise to span length are as follows:

Solid-rib structures	0.2
Braced-rib structures	0.225
Spandrel-braced structures (with hinge above)	0.25

These values may be either increased or decreased by 0.025 without making any material difference in the economics.

For three-hinged half-through, arch bridges, the average economic ratios of rise to span-length are as follows:

Solid-rib structures	0.225
Braced-rib structures	0.3

For three-hinged, high-deck, arch bridges, they are as follows:

Solid-rib structures	0.25 to 0.28
Braced-rib structures	0.33 to 0.38

For two-hinged arches and combined two-hinged and three-hinged arches, the economic ratios of rise to span will be practically the same as for three-hinged structures.

For the hingeless arch, a somewhat greater ratio of rise to span than that for the three-hinged arch is economical. The single test of this made for the 500-ft. span indicates that the best ratio is about 0.28 with low-grade deck, 0.33 for half-through arches, and 0.38 with high-grade deck.

Second.—In respect to solid-rib arches, the question of economic depth of rib does not arise; for the depth should always be made as great as a proper consideration of the section for resisting compression will permit. For braced-rib, three-hinged arches the economic rib-depth is about 7.5% of the span length, but quite a variation from that percentage may be made without materially increasing the weight of the metal. The economic average depths for hingeless and two-hinged arches will be about the same as the economic depths for three-hinged arches. The best form for a two-hinged arch is the crescent shape, but there is no great economy in this over the rib with uniform depth. The best shape for the hingeless arch is secured by making the depth at the crown about one-half of that at the springing points. Such a layout, as shown in Fig. 11, tends not only toward uniformity of chord section, but also toward esthetics.

Third.—It was found for all cases that the most economic location for the crown-hinge in a spandrel-braced arch is in the top chord. In braced-rib and solid-rib arches, however, the hinge should always be placed at mid-depth, so as to distribute properly the thrust over the two chords.

Fourth.—Comparing the economics of solid-rib, braced-rib, and spandrel-braced arches, it was found that the first mentioned is always considerably heavier than either of the others; and, under normal conditions of the metal market, it is also more expensive. The spandrel-braced arch requires for long spans a little more metal than the braced-rib arch; but, in case of cantilevering, this would generally be offset by the extra quantity of erection metal needed for the braced-rib structure. In short spans, the spandrel-braced arch is a trifle the lighter.

Fifth.—Comparing three-hinged, two-hinged, and hingeless arches, it was found that the three-hinged is a little heavier than the two-hinged, but nearly always lighter than the hingeless. The variations in weight among the three types, however, are never great.

Sixth.—The combination of three hinges for dead load and two hinges for live load produces very little saving over the three-hinged type; but it adds materially to the rigidity. In the writer's opinion, the combined type is preferable to any of the others.

Seventh.—When an arch is flanked by other spans than arches, there is generally quite a little economy involved by cantilevering the ends of the arch and shortening the lengths of the simple spans. The best proportions for lengths of cantilever arm and suspended span to total length of flanking span are, respectively, 0.4 and 0.6.

Eighth.—The ratios of weights of arches to the weights of the corresponding simple spans for both railway and highway bridges have been determined and plotted. As was anticipated, the arch usually effects a greater relative economy in highway structures than in railway structures of the same span length; and, the longer the span the greater always is the proportionate saving of metal.

As a conclusion to this paper, the writer begs to quote from one of his previous publications as follows:

"In dealing with the comparative economics of arches and simple trusses, it must not be forgotten that there are other factors than mere weight of metal involved; for the pound price of the manufactured material is generally somewhat greater for the former, and sometimes the cost of erection also is larger. Again, the comparison of the costs of arch superstructures and truss superstructures alone is not of much importance; for an economic investigation, to be of any value, must include both substructure and superstructure; and the costs of the former are likely to be very different in arch designs and simple-truss designs for any crossing".

The thanks of the writer are due to D. B. Steinman, Assoc. M. Am. Soc. C. E., one of the associate engineers of his firm, for expert assistance in making certain graphic calculations by which a number of important points of economics determined in this paper were solved.

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PAPERS AND DISCUSSIONS

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HYDRAULIC PHENOMENA AND THE EFFECT OF SPREADING OF FLOOD WATER IN THE SAN BERNARDINO BASIN, SOUTHERN CALIFORNIA

Discussion.*

By Messrs. James Hyde Forbes and A. L. Sonderegger.†

James Hyde Forbes,‡ Jun. Am. Soc. C. E. (by letter).§—The writer has read this paper with interest, but is somewhat disappointed at the brevity with which the author has treated some phases of a subject on which many interesting data were collected and studied. It was the writer's privilege to be associated with the author, J. B. Lippincott, M. Am. Soc. C. E., and Mr. Kingsbury Sandborn in the recent litigation between the City of San Bernardino and the City of Riverside, being engaged in the collection, study, and preparation of data for presentation in Court, 7 months of continuous residence having been spent in the vicinity studied, for 2 months of which he was at the spreading works. Mr. Forbes.

As the hydraulic phenomena are entirely due to geologic conditions, the writer believes that a more detailed geologic description would add to the interest of the paper.

Geologic History of the San Bernardino Basin.—The mountains limiting the basin on the northeast are of granite of an early geologic age, in fact, they are the basement complex of this region. Lenses of secondary crystalline limestone are contained in the granite mass, but there are no evidences of late volcanic intrusions or "dikes". South-

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* Discussion of the paper by A. L. Sonderegger, M. Am. Soc. C. E., continued from November, 1917, *Proceedings*.

† Author's closure.

‡ Lindsay, Cal.

§ Received by the Secretary, December 31st, 1917.

Mr. Forbes. east and northwest of the basin are other ranges of granite, and there are outcropping points of granite south of it, so that its main base or floor is composed of an impervious granite mass.

These granite ranges are of complex structure, and have been greatly faulted. The main trend of the major structure lines is northwest-southeast, in common with those of the Coast Ranges of Southern California. These structure lines were established at an early period, and later strains have adjusted themselves along the same lines. The major faults extend for many miles, following the same general trend, on each side of the basin. The great San Andreas fault, running through San Gorgonia and Cajon Passes, can be traced along the base of the mountains forming the northern limit of the basin. A minor series of structural lines lies just north and south of it. The San Jacinto fault also is a major structural feature, easily recognized from the topography, extending along the base of the San Jacinto Mountains across the San Bernardino Valley above Colton and through Lytle Canyon. About 5 miles west of the mouth of Lytle Creek, the San Jacinto fault converges into the San Andreas fault, making those two structural features of practically one zone. The steep sides of the mountains are immense fault scarps, greatly shattered and metamorphosed.

The granite masses in the San Bernardino Basin have been extensively deformed, and the deformation is expressed in a series of block faults. Massive granite is primarily an igneous magma of crystalline character, but it is often subjected to stresses such that the granite is broken into huge blocks which are tilted and displaced with reference to each other. In the immediate vicinity of some of the fault zones, in the instant case, the granite has been metamorphosed by intense pressure and frictional heat, and has taken the form of schists and gneiss.

As faults are joints or cracks in the rock formation along which the strata have been displaced, the result, whether the displacement is slight or great, is a break in the continuity of the strata, with a line of rupture, or a zone of fractured material, normal to the stratification. These fault zones allow a free movement of absorbed water to considerable depths, and this water may take up the heat generated by the friction of the grinding mass. The close relation of hot springs and hot wells to fault zones is generally understood, and, where fault lines are lost in alluvial valleys, they may often be traced by hot springs and wells.

The faults, marking the lines along which the main subsidence of the San Bernardino Basin block has occurred, are shown by the topography west of the valley. A fault scarp forming the south side of Cajon Canyon is the northern line; that on the south side of Lytle Creek is the southern line. The general change in elevation of the topography between is the greatest feature, indicating a subsidence. North of Cajon Canyon and south of Lytle Canyon, the elevations are 5 000 ft. and more, but between these two canyons the maximum elevation is 3 750 ft. Mr. Forbes.

Previous to the deformation which resulted in the differentiation of highlands and lowlands, the topography was somewhat level and the mountains were low. This is deduced from the present topography of Perris Valley and the top of the table-land at Bear Valley. An old lake occupied the lowest and largest part of the valley. In this was deposited the fine sands and gravel which make up the earliest sedimentary formation. These sediments are sands, clays, and gravel; the sands are fine-grained and mica is abundant. The fact that the ferro-magnesium minerals are not broken down through oxidation attests to deep-water deposition. In places, the clays are metamorphosed somewhat, producing shale. East of the basin this slightly consolidated stratified material has been gently folded and bent, adjusting itself to the crustal movements of the underlying granite. The period of deposition was brought to a close by crustal movements which occurred along the major fault lines previously described and the minor structure lines related to these fault zones. It was then that the San Bernardino Mountains were raised above the floor of the valley. Contemporaneous with this movement was the San Jacinto-Bunker Hill fault movement, which formed the San Jacinto Mountains and caused the subsidence of the San Bernardino Valley between the Bunker Hill fault and the San Bernardino Mountains, forming the San Bernardino Basin.

At the end of this movement, the older alluvium was deposited by the streams which, under the new topographical conditions, had higher and more precipitous water-sheds. This older alluvium consists of extensive deposits of coarse boulders and gravel at the canyon mouths and lenses of gravels and stream-formed clay and sand throughout the valley, laid down about in the manner that the present deposition is being carried on. The red mesa lands are stream deposits, being mostly the weathered product of the eroded earliest sediments with the original abundant ferro-magnesium minerals oxidized into red iron oxide.

Further movement along the same lines followed the deposition of the older alluvium, and still continues to some extent. In old histories of the valley we find records of earthquakes felt intensely in the vicinity of the Bunker Hill and Perris Hill faults as early as 1813. The more recent displacements along the Bunker Hill-San Jacinto fault are those of December 25th, 1899, and June 20th, 1915. We find at the present time the red soil and boulder cones lifted above and tilted toward the present valley floor. This indicates the subsequent movements along the structure lines, resulting in the present height of the San Ber-

Mr. Forbes. nardino Mountains, also probably a subsequent greater subsidence of the basin trough and a rise of the Bunker Hill fault scarp.

Erosion and resulting deposition were carried on at a rapid rate, and filled the valley to its present level with the later or present alluvium, the total depth of which is unknown. Wells have been sunk to below sea level and have not encountered the granite bed-rock or even the younger shales of the earliest sedimentary period. The bulk of this alluvial fill is material laid down by streams. The streams were exceedingly irregular and intermittent in their flow, depending, as they do at present, on the sudden and capricious visitations of heavy storms. The Santa Ana River flowed west at times along the northern limit of its cone, and at such times it eroded the mesas along the base of the mountains, which were composed of coarse gravel and boulders, as is shown in the remnants still exposed. The floods picked up this coarse material and carried it farther, each successive flood moving it forward until it reached a lower portion of the valley, where, with the decrease in velocities, it was dropped. In this way the coarse gravels deposited in the Santa Ana cone are accounted for.

Stream-built slopes reflect the size and drainage area of their canyons. The short, steep canyons of the streams on the north side of the valley between the Santa Ana River and Cajon Creek have short, steep cones. Their brief torrential floods sweep the coarse débris to the mouths of the canyons, but cannot carry it far beyond, as the streams decrease in volume rapidly through seepage. The longer canyons, with larger drainage areas, have more gentle gradients, and their floods, being of longer duration and greater volume, advance farther into the valley. Consequently, their fans are larger and more gently inclined.

The topography is such as to have always confined the Santa Ana River within the limits of the basin, that stream having always escaped from it in or about the same position as it does now, namely, between the Box Springs Mountains and the granite hills west of Colton. Therefore, it must be concluded that this stream has been the main factor in the upbuilding of the basin. The next largest and most productive tributary drainage area is that of Lytle Creek. This creek, however, has not been as great a factor in the building up of the basin fill, because, only recently, by fault movement, has it been confined to the basin, its depositions previously having built up a considerable fan outside of the latter.

The course of each stream has always been, directly or indirectly, from the mouth of its canyon to the outlet from the valley, yet, between these points, the course has varied greatly from time to time; and this is more especially true of the larger streams. The Santa Ana River has doubtless shifted and wandered over the valley from the southern to the northern limit of the Artesian basin, flowing in widely different directions at different times and at different levels. Its old channels, in the nature of things, much broken and impaired, now lie buried beneath the hundreds of feet of later deposits. All those old channels headed in the coarse gravel of the débris cone at the mouth of the canyon, and all still lead the water ultimately, and by devious courses, to the comparatively limited outlet from the valley, as water sinking near the mouth of the canyon finds its way largely into the coarse gravels at the head of these old gravel channels, and the course that any portion of such water takes depends on the line of least resistance, which, for the most part, must be what remains of the course of the particular old channel that it happens to enter. Mr. Forbes.

The position of the axis or lowest point of a valley depends on the relative size of the opposing cones. In this valley the present axis is Warm Creek, but it is reasonable to believe that, before the present course of Lytle Creek was established, the axis was farther west. The Lytle Creek cone has recently overlapped the Santa Ana cone, thus moving the axis east.

The most significant and conspicuous topographical feature of the basin is the escarpment in the valley till of unconsolidated materials (marked as a distinct ridge where erosion has not entirely effaced it) of the Bunker Hill-San Jacinto fault. Mr. Sonderegger, on page 1476,* refers to the underground basin being closed by a subterranean barrier known as "Bunker Hill Dike", said to occupy a portion in the alluvium along this fault line and consisting of impervious clays which effectively close the Basin and force practically all the underflow to the surface. From the writer's detailed study of this feature and his experience in like situations where fault movements have caused a break in the continuity of strata in alluvial materials (such as the Niles-Irvington fault across the Niles cone, in Alameda County, California), it is, to his mind, a decided misconception of the formation of the valley and of the geological agencies which led to it, to consider the Bunker Hill fault as a fold of impervious material, or "dike".

A detailed study of material found on the fault scarp or Bunker Hill Ridge and of the penetration records of wells near the ridge convinced the writer that the materials were entirely stream deposited, for the most part sand and gravel. West of Mt. Vernon Avenue the gravels found were typical of the country rock characteristic of the Lytle Creek drainage area. Near the Santa Ana River the materials were coarser, and carried the pink gravel characteristic of the formations of the Santa Ana River drainage area.

The Bunker Hill fault has simply caused a vertical shearing and displacement of the lenses of coarse and fine material through which it passes, thus interfering with their continuity and the passage of water through them. It is often true, when fractures occur in massive bed-rock, that the overlying stratified deposits may be bent or folded

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* *Proceedings*, Am. Soc. C. E., September, 1917.

Mr. Forbes. to a slight degree, provided they are consolidated. It is impossible to bend or fold unconsolidated lenses of sand, gravel and clay, to form a "dike" such as is considered by Mr. Sonderegger; deformation in such cases causes an abrupt break and a shearing of the various lenses, with the result that sheared lenses of coarse gravels subsequently abut against fine material. Where the lenses of fine materials predominate in the valley fill, a deformation and shearing effectively blocks or retards the transmission of ground-water at the line of deformation. Conversely, where coarse gravel and sand lenses predominate, fault movement, taking place largely in open materials, interposes no appreciable quantity of material resistant to water movement, and percolation continues through the line of deformation at nearly the same rate as it maintains above or below that line. As has been stated previously, the Santa Ana River always left the valley approximately in the same locality, flowing at right angles to the fault trend. The result of this condition was a relatively coarse and uniform deposition in this region where the fault subsequently crossed the Santa Ana River, and the displacement, in this area, is less effective as a dam than elsewhere, because of the more open and consistent character of the deposited material. The ground-water here moved uniformly through the porous mass from bed-rock to the surface and continued to do so after faulting nearly as freely as before. Where the fault trend parallels the course of Lytle Creek, however, the ground-water levels show that it acts as a very effective dam, the gravel channels apparently being blocked by materials more resistant to percolation.

Many drillers' logs of wells were obtained and studied. The logs for the most part are vague, as each driller has his own idea of what should be called fine or coarse gravels and what material should be classed as clay. In some localities, due to recently made borings, the actual drillings were available. In no portion of the valley, however, was there found a continuous impervious clay stratum, as assumed by the author. The clay masses occur, not as continuous blankets, but as rather limited lenticular bodies, the records being in full accord with the recognized geologic theory of stream-deposited clays. In this case, the well logs were too scattered to correlate, except in a very general way. The sands, clays, and gravels, furthermore, are so commingled that to attempt to identify and correlate certain strata would be highly speculative. However, in the penetration records of numerous wells near the Bunker Hill fault scarp, there was recorded the presence of recent swamp materials at relatively shallow and similar depths, which might be correlated to indicate limited clay blankets in this vicinity.

It seems to the writer that Mr. Sonderegger's conception of the Artesian conditions as "phenomenal" is due to his starting with false premises, namely that the basin is closed by a continuous impervious subterranean barrier and the presence of continuous clay blankets, the

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border of which is termed by him the "Artesian rim". The "hydraulic phenomena" are the natural results of existing climatic and geologic conditions, climatic in that the water supply is entirely dependent on the seasonal rainfall on the contributing water-shed, and geologic in that the water is impounded underground.

Neither an impervious clay blanket nor an impervious barrier entirely closing the basin is a necessary condition for a flowing well in the San Bernardino Basin. The necessary conditions for Artesian flow are an adequate source of pressure through the body of ground-water extending to a level higher than the mouth of the well, and a retaining agent offering more resistance to the upward passage of water than the well which pierces the resistant material. (It is a well-known fact that there are Artesian wells on the sand dunes of Long Island, New York.) In the San Bernardino Basin the height of the ground-water in the apex of the Santa Ana cone, which stands at a considerable elevation above the mouths of the wells in the lower portion of the basin, exerts a pressure which acts with equal intensity throughout the cone. The frictional resistance of the porous fill retards the movements of the ground-water, causing a loss of head and establishing hydraulic grade. If it were not for the release of pressure due to the transmission of ground-water from the basin through a section of the fault line in the vicinity of the present Santa Ana channel, a uniform hydraulic grade would be maintained under the whole Santa Ana cone. Contrary to this, and to Mr. Sonderegger's theory of an entirely closed basin, an hydraulic grade is established and shown by the relatively high water pressures in the deep wells in that portion of the basin locally called the Antil region (in the central part of the valley east and south of Warm Creek); a steeper grade, with its lower water pressures, is exhibited by wells of similar depth near the Santa Ana River channel.

Different water pressures exhibited by wells on the Santa Ana cone with a common source of supply are due, in some degree, to the depth of the column of resisting materials removed in drilling the well. The wells in the Antil region are from 600 to 1 000 ft. deep—the point of entrance of the water into the well casing being at the bottom, at an elevation ranging from sea level to 400 ft. above. The elevation of the water-table 2 miles east of Orange Street on the Santa Ana cone was about 1 400 ft. in April, 1915. The head or difference in elevation between a high point of the water-table and the bottom of the wells might be more than 1 000 ft. The pressure exerted by the ground-water at any point in the valley fill is that due to elevation or pressure head, with the water exerting an upward pressure and endeavoring to seek its level, as well as a horizontal pressure or velocity head. Both the velocity head and pressure head are overcome, in great degree, by the frictional resistance of the material through which the water is trans-

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mitted. A column of resisting material is removed in drilling a well, and the degree to which the pressure head becomes effective depends on the depth of this resisting column. Just why Mr. Sonderegger has eliminated the body of ground-water higher than the 1 150-ft. contour (page 1484)* as a source of pressure is not explained. If the frictional resistance of the porous media were a known factor, the exact source of pressure might be determined; but the writer believes that the pressure head of the higher body of ground-water east of the 1 150-ft. contour is essential to overcome the resistance and cause the water in the wells to rise above the ground surface and exhibit pressures of from 20 to 30 lb. per sq. in.

There were other wells in the same locality as the deep, high-pressure wells; those from 250 to 300 ft. in depth were designated as low-pressure wells, having Artesian flow but exhibiting pressures of only from 6 to 12 lb. per sq. in.; among the shallow wells, the water level was below the ground surface, and they are termed surface wells. This variance in water pressure and water level in the wells is attributed to the difference in elevation between the height of the source of supply and the bottom of the well casings, at which point the water, released by the removal of the resistant material, is received. It might be well to explain that in the San Bernardino Basin the general practice in drilling Artesian wells is to sink a casing to a gravel stratum and leave the bottom open, not perforating the casing at any intervening level.

The author states (page 1488) that the "friction head" between the Artesian rim and Kehl flume well was approximately 2 ft. per thousand, and was caused by the natural leakage. The writer cannot agree with Mr. Sonderegger that the loss of head due to frictional resistance of the porous fill is only 2 ft. per thousand, as he has made experiments in a limited way, in coarse sand and gravel, and has found a minimum loss of head at the rate of 1 ft. in fifty. The "Artesian rim" is that topographical contour at which the difference between the elevation of the impounded ground-water in the upper cone and the mouth of the well has sufficient head to overcome the frictional resistance of the material and cause water, released through a well, to rise to the surface. Naturally, this "rim" will fluctuate with the height of the water in the upper cone, and swamps will appear at higher levels in wet years than in dry ones. The writer believes that Mr. Sonderegger's conception of the necessity of a confining clay blanket and (page 1483) that the high-water plane, *C-C*, causes an overflow at the edge of the clay strata (or Artesian rim), manifested by the appearance of swamps, is in error.

The original source of all the ground-water, whether near the surface or in deep Artesian wells, is the rainfall, and the author has presented very clearly the relation between water-level records and the cumulative rainfall record. The water-table is the surface below which the pores and crevices of earth are saturated. The elevation of this water-table varies with the vagaries of the rainfall, which governs the quantity of water available for absorption. The underground reservoir is so large that a single dry year would not show a marked decline in the water-table. Where there is an accumulation of years when the rainfall is below the average, a marked decline is seen. Mr. Forbes

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* *Proceedings,* Am. Soc. C. E., September, 1917.

Interpretation of the Water-Table Contours.—The writer has plotted the water-plane contours from actual measurements of surface wells in the valley, the latter indicating the highest point of the zone of saturation, and showing the direction of the flow, extent, and source of the ground-water. Considering the formation of the valley, the comparative size of the cones, and the plotted water contours it was readily seen that the principal source of ground-water of the basin and of hydrostatic pressure for the deeper seated waters, is the impounded water in the Santa Ana cone, contributed by natural seepage from the Santa Ana River and controlled seepage from conservation processes. Wells on the same cone derive their supply from a common source—the saturated sands and gravels lying at the mouths of the canyons, and whatever reduces the quantity of water in that body affects, in a general way, the entire cone.

There is to be expected a decided annual variation in head in all the wells in the valley, due to the replenishment of the apexes of the cones during the winter, and a drop due to withdrawal, natural and artificial, during the summer. The cycles of dry and wet years have an accumulative effect over longer periods.

The topography of the water-table underlying the débris-filled valley conforms in general to that of the land surface, but the slopes are more gentle. The greatest slope of the water-table is toward the mouths of the canyons, whence comes the principal supply. However, the surface rises more rapidly, and, although the water-table in the central part of the valley is near the surface, it becomes gradually deeper in the direction of the canyons. The greatest drop in the water-table during the summer is at the mouths of the canyons. As the water maintains its hydraulic grade and is in constant motion, any depletion in the central part of the valley is supplied from the high cones, giving consideration to the retardation due to the frictional resistance of the porous media. Therefore, it is best for the economic use of the basin to draw down the water-table in order to allow the greatest replenishment, whether natural or effected by conservation processes.

The water-table has a definite gradient, and the ground-water is in a state of continual motion, as the water-contour lines indicate that there is some escape for the water at lower levels than that where it enters. Because of the pressure gradient exhibited by the Artesian water, it is known that the water in the deeper gravels also has motion. This would not be consistent with a barrier condition closing the basin.

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such as has been described by Mr. Sonderegger, the contour lines showing the water-table to be continuous from the basin and across the fault line at the point where the Santa Ana River crosses it to Riverside and the valley. West of Bunker Hill, on the Lytle Creek cone, there is an abrupt drop in the ground-water level from the basin toward the southwest. If a fold of impervious material existed, as suggested by Mr. Sonderegger, the basin would be like an artificial reservoir, and the ground-water might be lowered below the lip of the barrier by draft, due to pumping from the wells and depleting the stored water supply. There is no such condition in the San Bernardino Valley Basin. The lowering of the water-plane during the period from 1894 to 1904 was not an indication that the basin had been over-developed and permanently depleted, but, as clearly presented by Mr. Sonderegger through the use of residual mass diagrams of rainfall, due to the diminishing surface water supply during a cycle of dry years. The outflow from the basin continued at about the same rate as during prior years, but the supply was reduced; consequently there was a lowering of the water-table level.

The writer's contours represented the water-table position of April 5th, 1915, being that of the highest point in the replenishing period. The broad and steeply inclined underflow from the west is due to the percolation from Mill Creek, Santa Ana River, and Plunge Creek, greatly increased through the process of conservation carried on in the Santa Ana wash. This broad underflow conforms in shape to the débris cone. The City Creek underflow meets that from the west and adds its bulk to the main body. In fact, each of these streams has an independent cone, which broadens and flattens, coalescing at its periphery with that of the Santa Ana River, until the whole makes one body of water underlying the Santa Ana cone, with a constricted point of free escape between the Bunker Hill and Reche Canyons. The continuity of the water-table north and south of this line shows a continuous outflow from the surface to bed-rock. If there was an impervious dam entirely across the mouth of the basin, the decided drop in the water-table would be continuous. In fact, the draft in the water-table below Colton would be such as to bring about such a phenomenon. The water underneath is necessary to support the upper water in the zone of saturation.

There are streams of rising water in the San Bernardino Basin, namely Warm Creek, Towne Creek, and the lower ends of the channels of City Creek and the Santa Ana River. The ground-water emerges to the surface wherever the water level within the alluvial cone becomes higher than that of the lowest depression or level of the surface. In some confined low points the soil is soft and boggy, and swamps are formed. In the case of a continuous depression, as in the stream channels of the basin, the seepage water forms a "making" stream entering the channel above and below the water level along the sides and bottom of the channel. The writer's water-table contour lines show points at which the water-table was higher than the ground surface in April, 1915. Mr. Forbes.

The water of Warm Creek is appropriated by the Riverside Water Company, which also owns numerous wells near the Warm Creek channel. When the water-table lowers, during cycles of dry years and in the latter part of each season, the flow in Warm Creek correspondingly decreases. The Riverside Water Company then allows its deep wells to flow into Warm Creek, increasing the flow to the necessary volume. The deep wells in the Antil region, owned by the City of San Bernardino, are used for municipal water supply. A number of the deep wells have a flow ranging from 100 to 125 in. of water.

The writer submits the following conclusions which he formulated after several months' study of conditions in the basin:

1.—That an impervious barrier across the entire valley above Colton is not necessary to Artesian flow, and does not exist.

2.—That there is no continuous impervious clay blanket overlying the valley. The pressure encountered in deep wells is due to the hydrostatic head, accounted for by the columns of water high in the débris cones standing at an elevation higher than the mouths of the wells.

3.—That the pressure in the different wells on the same débris cone varies according to the depth of resistant material removed and the difference in effective pressure head.

4.—That there is a constant flow of ground-water out of this basin, but the retarding effect of a constricted point of free escape makes possible a storage reservoir.

5.—That the original source of all the ground-water is the rainfall; and the height of the water-table depends on there being an adequate supply of rainfall.

6.—That the greatest drop in the water-table occurs annually in the apexes of the débris cones, where the water is not of economic importance to the overlying lands, and that, for the economic use of the basin as a storage reservoir, this depletion should be accomplished in order to allow the greatest replenishment, natural and through conservation processes, in the flood period.

7.—That Warm Creek and other "making" streams are seepage-water streams; and that the water impounded in the valley fill, raising the elevation of the water-table to heights above the surface channels of these streams traversing the valley, increases through seepage the summer flow of these streams, and, therefore, is not waste, but of economic importance.

8.—That the lenses of gravel deposited by the Santa Ana River are in contact with the mass of coarse material at the mouth of the Santa Ana Canyon, and extend to the northern limits marked by Warm

Mr. Forbes. Creek and to the west beyond Warm Creek and out of the valley between the granite mountains. These lenses, acting as a porous medium for the flow of water, receive their supply through natural seepage from the waters of Mill Creek, Santa Ana River, Plunge and City Creeks, and distribute it underground to the limits of the cone.

9.—That, through the spreading of flood waters, the natural seepage may be increased on the Santa Ana cone so that there is little danger of an over-development of the basin.

10.—That the San Bernardino Valley presents the largest underground storage basin in Southern California, and the most important, in view of its natural adaptability as a reservoir and its economic development.

11.—That future development should take place north of the Santa Ana River channel and west of Warm Creek, in order to obtain the maximum supply of water.

Mr. Sonderegger. A. L. SONDEREGGER,* M. Am. Soc. C. E. (by letter).†—The statement that the evaporation from swamps in Southern California is approximately 96 in. is a deduction from experiments made in Owens Valley by Charles H. Lee,‡ Assoc. M. Am. Soc. C. E., relative to losses by absorption by plant life. He states that the loss by transpiration in freshly-cut alfalfa was 0.498 in. in depth per 24 hours, as compared with 0.3 in. of evaporation from a pan in Owens River, and of 0.38 in. from a shallow pan in the soil. Furthermore, he says:

> "The results obtained by German investigators indicate the loss from sod during the growing season to be 92% greater than from water surfaces, and that from cereals to be 73% greater. Furthermore, the humidity of the air after passing over an alfalfa field is very noticeably greater than after crossing a body of water."

From these observations the writer has deduced that the loss by evaporation from swampy areas with standing water and prolific vegetation would probably be 1⅓ times as great as that from still water; however, actual experiments might lead to somewhat different results.

In regard to the determination of the benefit derived from the spreading of flood water on the débris cone, more accurate results would be obtained by systematic measurements of the fluctuation in the water-plane in the upper parts of the débris cone, which are now lacking, and of pressure and discharge measurements of wells within the Artesian basin, which at present are only fragmentary.

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* Los Angeles, Cal.

† Received by the Secretary, February 14th, 1918.

‡ *Water-Supply Paper No. 294*, pp. 60 to 63.

Much credit is to be given to the officials of the Riverside Water Company and of the Gage Canal Company, who, long ago, recognized the value of systematic well records. Mr. Sonderegger.

The point made by Mr. Lee in regard to the net annual volume absorbed is, in part, well taken. There is an unknown portion of the quantity of artificial absorption caused by waste and seepage from the diversion ditches which tap the Santa Ana River at the mouth of the canyon—that is, at the uppermost portion of the débris cone, leading from there for a considerable distance along the margin of the cone. These ditches are not lined; during past years, owing to excessive stream flow, they have carried and wasted ever increasing quantities of water, both during the wet and the dry seasons, and it is difficult to estimate the seepage resulting from them.

The writer has recommended the co-operation of the ditch companies with the conservation association, by which these ditches may be used for diversions, for spreading purposes, enabling the application of spread-water at the very apex of the cone.

The value of spreading flood waters is rapidly becoming more generally recognized, not only for purposes of conservation, but also for flood control. With the dry rivers of Southern California, particularly in the alluvial zone, where the soil is a sandy loam mixed with disintegrated granite, and extremely easily eroded, the destructive action of a flood occurs generally for some time after the peak has passed. It is admitted that spreading is not practicable during the very peak of a flood, and may not help to reduce such a peak, especially during floods of unusual intensity; but, after the peak has subsided, the rivers carry a moderate discharge often for weeks. Grades in the alluvial zone are generally steep—from 15 to 50 ft. per mile being very common—resulting in high velocities. The effect is that, after the peak, the water-soaked banks readily succumb to the attack by a meandering stream, and it often has happened, particularly during moderate floods, that the greatest damage occurs after the flood has subsided. To prevent such damage, spreading is as effective as it is economical, fulfilling a twofold purpose.

The following is a brief bibliography on the subject:

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W. E. Spear. "Study of the Water Supply Sources of Long Island." Report of Comm. on Additional Water Supply of New York City, Appendix 7, 1903, pp. 753 and 817.

Report of Conservation Commission of California, 1912. Charles H. Lee. "Subterranean Storage of Floodwater by Artificial Methods in San Bernardino Valley."

Mr. Sonderegger.

Evaporation:

Water-Supply Paper No. 294. "An Intense Study of the Water Resources of a Part of Owens Valley". Charles H. Lee.

Agricultural Bulletin No. 177. "Evaporation Losses in Irrigation." S. Fortier.

The San Bernardino Basin:

Water Supply Papers Nos. 59 and 60. J. B. Lippincott. "Development and Application of Water near San Bernardino, Colton, and Riverside."

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AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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PULSATIONS IN PIPE LINES, AS SHOWN BY SOME RECENT TESTS

Discussion.*

By H. C. Vensano, M. Am. Soc. C. E.†

H. C. Vensano,‡ M. Am. Soc. C. E. (by letter).§—The writer desires to thank Messrs. Gibson, Hering and Johnson for their criticisms. As Mr. Johnson's criticism is of the destructive variety, it is not very helpful. His contention, that the agreement between the formula advanced and the experimental work is merely a coincidence, is scarcely to be taken seriously, especially, when the writer adds that in a previous set of experiments the time of gate opening was about 50 sec. Due to the fact that the recording apparatus was not registering properly, the charts were not preserved, but the results agreed quite well with the subsequent work. In these later experiments, varying times of gate opening would have been used had it been possible, but the plant was then operating to produce power, and the time of gate opening could not be changed. Mr. Vensano.

Mr. Gibson's criticism, on the other hand, is constructive, and is therefore of more interest. Due to the brief way in which Mr. Gibson has advanced his theory, the writer feels unable to comment on it. He will, meanwhile, take great interest in Mr. Gibson's coming paper.

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* Discussion of the paper by H. C. Vensano, M. Am. Soc. C. E., continued from December, 1917, *Proceedings*.

† Author's closure.

‡ San Francisco, Cal.

§ Received by the Secretary, February 14th, 1918.

Mr. Vensano It is to be noted, however, that though Mr. Gibson's mathematical illustration apparently agrees with the experimental results obtained by the writer, his diagram does not show that this would be the case. Unfortunately, it has not been extended to cover his mathematical illustration, but it is very evident that, with heads higher than 200 ft., his curves will approach Mr. Warren's very closely. Mr. Warren's curve gives results only about one-half as great as those obtained by the writer's formula and corroborated by his experiments.

Mr. Gibson's chief objection to the writer's formula is based on the fact that the assumption was made that "the penstock velocity was assumed to vary directly as the time of opening or closing the nozzle". The writer realized a slight weakness in his deductions, because of this very assumption, and purposely introduced Fig. 6 to show the degree of approximation involved in it. However, referring to this diagram, it will be noted that, during the opening of the nozzle, the ratio of nozzle opening to time is a constant, but the total change of nozzle velocity is only about 5 per cent. In other words, for the nozzle opening, this assumption is very close to the truth. For the nozzle closing, this is not so true, due to some variation in rate of gate motion, as shown by the diagram, but this change is very slight for the first 30 sec. of the gate motion. A study of the surges shown by the opening diagrams and also a study of the first 30-sec. period of the curve of the closing diagram will show that the writer's formula is accurate for these conditions, and would tend to prove that this assumption has very little bearing on the total result.

Mr. Gibson also makes a statement that his work is based on the work of Professor Joukovsky and takes into account all the factors considered by that writer, the apparent implication being that the writer's work did not take into account all such factors. This is not the case, and, as a matter of fact, all the writer's ideas were based on those of Joukovsky, and all like factors were considered and included in the formula advanced.

However, although the views expressed by Messrs. Gibson and Johnson are apparently considerably at variance with the writer's, some explanation of the differences may be possible. It is remarkable, sometimes, how different viewpoints lead to apparently widely different results. As Mr. Johnson apparently agrees with Mr. Gibson, and as both are interested in problems of power generation, it is possible that their research work has been with a view to voltage and speed control of electric generating apparatus. Also, in view of the fact that Mr. Gibson's diagrams deal only with low heads (200 ft. head being considered very low in Western practice), it is probable that the experiments which they refer to were made in connection with turbine installations; in other words, with a turbine acting as the pipe gate.

Mr. Vensano.

The writer's experiments, on the other hand, were made with a view to studying "water-hammer" as affecting the design of pipe lines. An impulse-wheel rather than a turbine installation was chosen for experimentation, for the reason that the small nozzle (gate) opening compared with the cross-section of the pipe line would give almost complete reflection of partial pressure waves at that end of the pipe. This condition of complete reflection would give the simplest and truest condition of water-hammer. It will be noted that, neglecting the 20- and 36-in. pipe, which is actually part of the nozzle body, the area of opening is only 2.2% of the cross-section of the pipe line for one nozzle opened, or about 9% with four nozzles opened.

In using a turbine as the gate control, one would ordinarily have a very large proportionate gate opening, practically oftentimes the full area of the pipe line. Under such circumstances, no reflection of partial pressure waves would be obtained until the gate was almost closed. A study of the writer's diagrams, Figs. 30 and 31, would indicate that, without reflection of partial pressure waves, the maximum pressure might rise to a higher value than given by his formula. This would in no wise minimize the usefulness of the formula submitted, but would represent a difference in physical conditions similar to that produced if sound-wave experiments were being performed on an open organ pipe, rather than on one with a closed end. The results would naturally be at variance.

The writer believes that future experiments should include a study of that ratio of gate opening to pipe cross-section at which reflection of partial pressure waves begins. For openings above such value, under which conditions secondary wave effects are doubtless produced, some extension of the formula submitted would, no doubt, have to be made, and these results would perhaps explain the high values advanced by Messrs. Gibson and Johnson, which they claim to be corroborated by low-head practice.

In conclusion, the writer is sorry that Mr. Johnson feels that the formula advanced "has no place in engineering literature," and believes that decision to be somewhat hasty. He trusts that future experiments will prove conclusively its usefulness.

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PAPERS AND DISCUSSIONS

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THE HELL GATE ARCH BRIDGE AND APPROACHES OF THE NEW YORK CONNECTING RAILROAD OVER THE EAST RIVER IN NEW YORK CITY

Discussion.*

By Henry B. Seaman, M. Am. Soc. C. E.

Henry B. Seaman,† M. Am. Soc. C. E. (by letter).‡—This description of the largest, the most scientific, and, it is believed, the most artistic bridge yet constructed, has been so complete that anything added might seem to be a presumption. It is probably the first large construction wherein was adopted the new method of proportioning, by which a static unit strain is allowed and the excess due to the action of the live load is provided for entirely by an impact formula. This method of proportioning is the most rational and the most scientific which has yet been used, and receives its ultimate interpretation in the present structure. After investigating the subject very thoroughly, while acting as Consulting Engineer to the Department of Bridges, New York City, the writer, later, took occasion to present the result of such study to the Society in 1912.§ It seems to be but a progressive step from that which was first instituted some thirty years ago by the late Charles C. Schneider, Past-President, Am. Soc. C. E. Mr. Seaman.

The description of the higher scientific characteristics of this structure have been thoroughly outlined by Mr. Ammann, but it might not

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* Discussion of the paper by O. H. Ammann, M. Am. Soc. C. E., continued from January, 1918, *Proceedings*.

† New York City.

‡ Received by the Secretary, November 20th, 1917.

§ "Specifications for the Design of Bridges and Subways", *Transactions*, Am. Soc. C. E., Vol. LXXV, p. 313.

Mr. Seaman.

be amiss, in a short space, to mention the methods adopted in erecting the tall masonry piers of the approach viaduct.

The foundations of these piers were not unusual in any way, but, being of reinforced concrete, of an extreme height of about 125 ft., and in a continued series about 90 ft. apart, the method of constructing them rapidly necessitated some new thought, or, as might be better expressed, new application of old principles.

At the time the contract for this masonry was undertaken, the method of chuting concrete from the mixer to its final disposition, by using a tower, had come into general use in concrete construction, and, after careful consideration of various other methods of procedure, this one was adopted as the most feasible for this work. It was proposed at first to adopt this method with four piers, but, on further consideration, it was decided to extend it to six piers as a unit. This arrangement necessitated an exceptionally tall tower (214 ft.). This was the highest free standing tower used up to that time, and it was held safely in position by a series of guys. Fig. 58 is a general view of this arrangement in service. The tower was built in sections 14 ft. long, with a special section for the top, to provide for the working sheaves, Fig. 60. These sections were built up with an erecting crane, Fig. 61, which was carried up with the tower as the erection proceeded, and was used as part of it while in service.

The planning of the construction of this masonry, which was in charge of the writer as Consulting Engineer for the contractor, was divided into three sections: first, that on Long Island, in charge of Mr. J. J. Smith as Superintendent; second, that on Wards Island and Little Hell Gate, in charge of James H. Small, Jr., Assoc. M. Am. Soc. C. E., as Superintendent; and third, that on Randalls Island and the Bronx Kill Bridge, in charge of Mr. Little as Superintendent. Each Superintendent arranged the details of his own work, but the general procedure, as outlined, was adopted on all sections, except that of Randalls Island, where the piers were lowest. There it seemed to be most expedient to place derricks on elevated platforms, and deposit the concrete by buckets, instead of by chutes. The work on Wards Island was perhaps the most carefully prepared in layout, and it was on this division that the most complete and satisfactory arrangement was made for handling the materials. A large set of bins for broken stone or gravel, sand, and cement was erected near the shore at Hell Gate, and the material was carried by a 20-in. belt conveyor from scows to the bins, Fig. 59. From these bins the material was dropped into cars especially constructed for the purpose, each having a capacity of about 12 cu. yd., and by this means conveyed to the mixer. The mixer was placed so that the charging hopper was set below the surface of the earth, thus permitting the material to be dropped in proper proportions directly into the hopper. The mixer was then charged and,

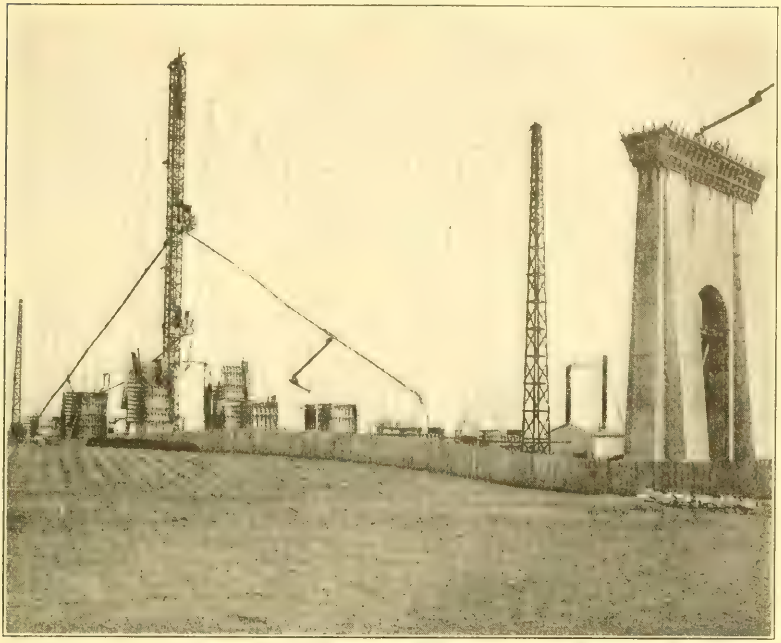


FIG. 58.—GENERAL ARRANGEMENT FOR CHUTING CONCRETE.

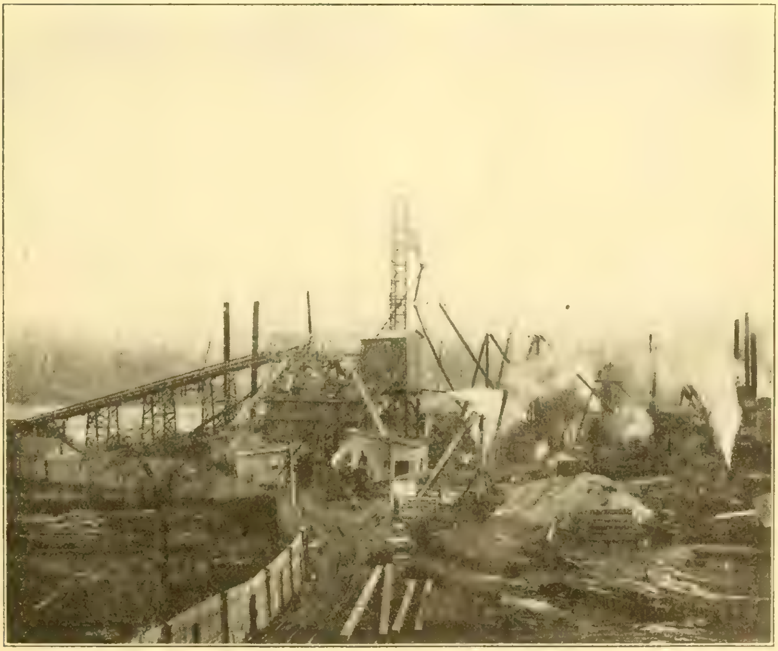
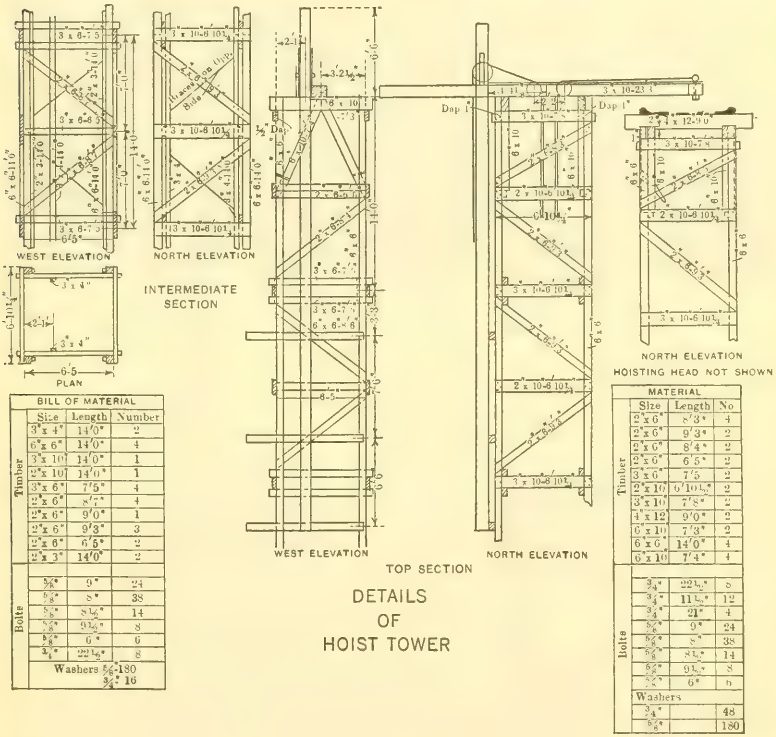


FIG. 59.—WARDS ISLAND UNLOADING PLANT.

after a rotation of about 1½ min., was discharged into the hoisting bucket and lifted to the chutes.

Mr. Seaman.

In the design of the forms, attention was paid to the importance of duplication, and standard sections were used from the top of the pier downward, the variation in height of the piers being provided for by the height of the first form placed. The forms were in sections of about 12 by 14 ft., and were made of 2-in ship-slab sheeting, planed on one side, with 4 by 8-in. studs, 2 ft. 6 in. apart. The forms were held in place by 6 by 8-in. wales, 6 ft. apart. These forms were bolted end to end, so as to prevent leakage. Adjustable corner forms were used at the recess of the pier. The heavy batter (1:1) at the base of the pier was made by a form of special construction. The arch centers were designed so as to throw the thrust directly on the pier as a buttress, and were supported by timbers set into the concrete. These timbers were arranged so that they could be unbolted and withdrawn without injury. Considerable difficulty was experienced in



BILL OF MATERIAL

	Size	Length	Number
Timber	3" x 4"	14'0"	2
	6" x 6"	14'0"	4
	3" x 10"	14'0"	1
	2" x 10"	14'0"	1
	3" x 6"	7'5"	4
	2" x 6"	8'7"	4
	2" x 6"	9'0"	1
	2" x 6"	9'3"	3
	2" x 6"	6'5"	2
	2" x 3"	14'0"	2
Bolts			
	5/8"	9"	24
	5/8"	8"	38
	5/8"	8½"	14
	5/8"	9½"	8
	5/8"	6"	6
	3/4"	22½"	8
	Washers 5/8"-180 3/4" 16		

MATERIAL

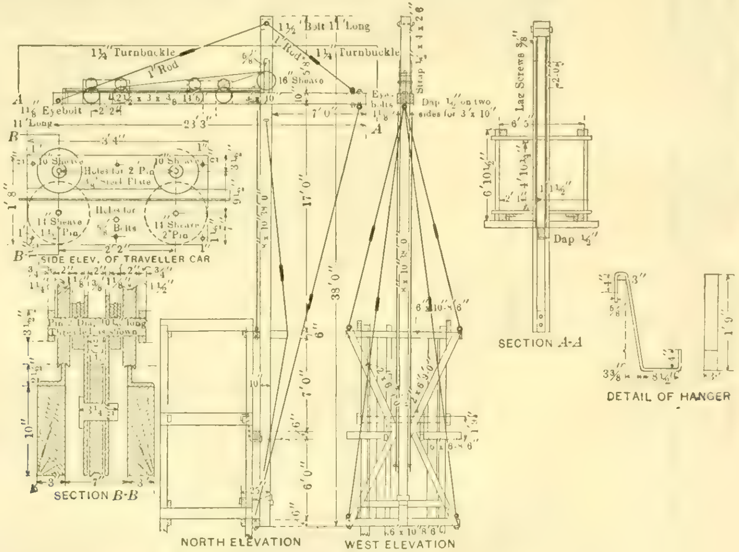
	Size	Length	No
Timber	2" x 6"	8'3"	4
	2" x 6"	9'3"	2
	2" x 6"	8'4"	2
	2" x 6"	6'5"	2
	3" x 6"	7'5	2
	2" x 10"	6'10½"	2
	3" x 10"	7'8"	2
	4" x 12	9'0"	2
	6" x 10	7'3"	2
	6" x 6"	14'0"	4
	6" x 10	7'4"	4
Bolts			
	3/4"	22½"	8
	3/4"	11½"	12
	3/4"	21"	4
	5/8"	9"	24
	5/8"	8"	38
	5/8"	8½"	14
	5/8"	9½"	8
	5/8"	6"	6
	Washers		
	3/4"		48
	5/8"		180

FIG. 60.

Mr. Seaman.

BILL OF MATERIAL

No. of Pieces	Discription	Size
	Timber	
1	Yellow Pine L. L.	8"x 10"-38'0"
2	" " "	3"x 10"-24'0"
3	" " "	6"x 6"- 8'6"
2	" " "	2"x 6"- 8'0"
2	" " "	2"x 10"-14'6"
	Iron —	
1	Trolley as per detail	
1	Sheave Bronze Bushed 2 Pin	16" Diam.
2	1" Rods, with 1¼" Turnbuckles	16' 8"
1	" " " "	8' 2"
2	" " " "	18' 7"
3	Eyebolt	1⅛"x 11"
1	"	1⅛"x 7"
2	Straps	½"x 4"x 2'6"
2	"	⅛"x 3"– 3'8"
1	"	½"x 4"-5'6"
14	Bolts	⅝"x 8½"
6	"	⅜"x 10½"
12	"	⅜"x 13½"
3	"	⅜"x 9½"
6	"	⅜"x 9"
16	Lag Screws	⅜"x 4"



DETAILS OF ERECTING CRANE FOR HOIST TOWER

FIG. 61.

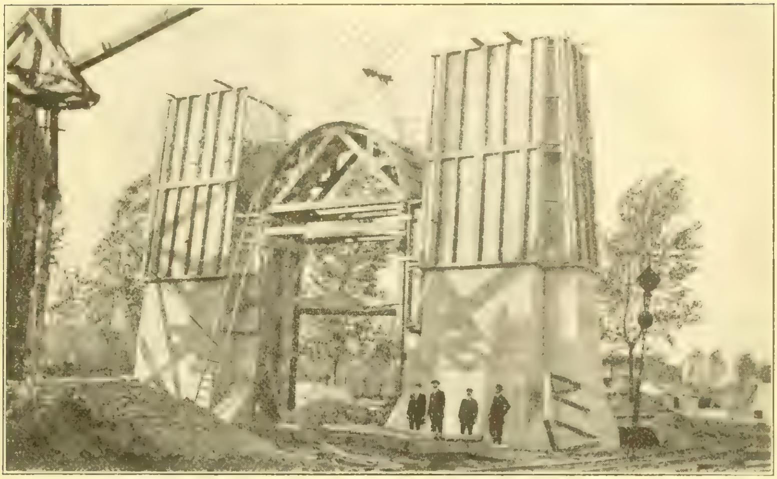


Fig. 62.—General Arrangement of Concrete Forms, Randalls Island.

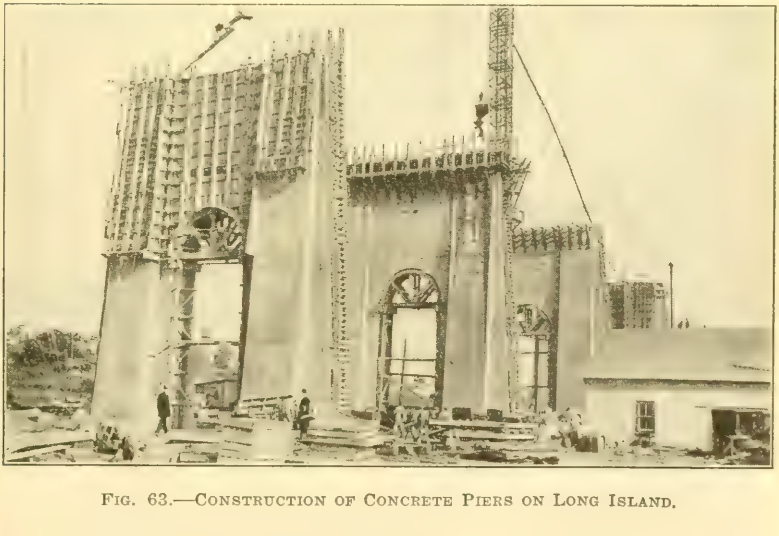


Fig. 63.—Construction of Concrete Piers on Long Island.

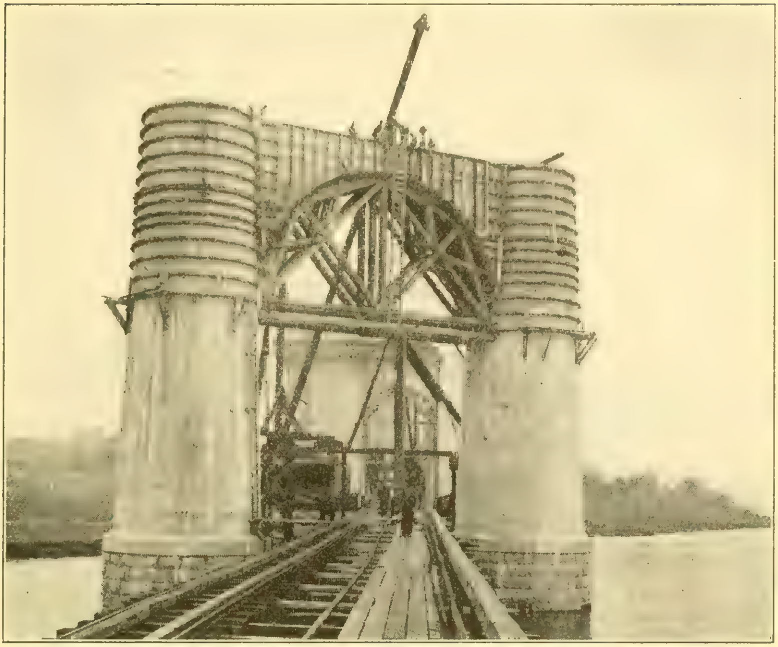


FIG. 64.—FORMS AND CENTERS IN PLACE FOR PIERS OF LITTLE HELL GATE BRIDGE.

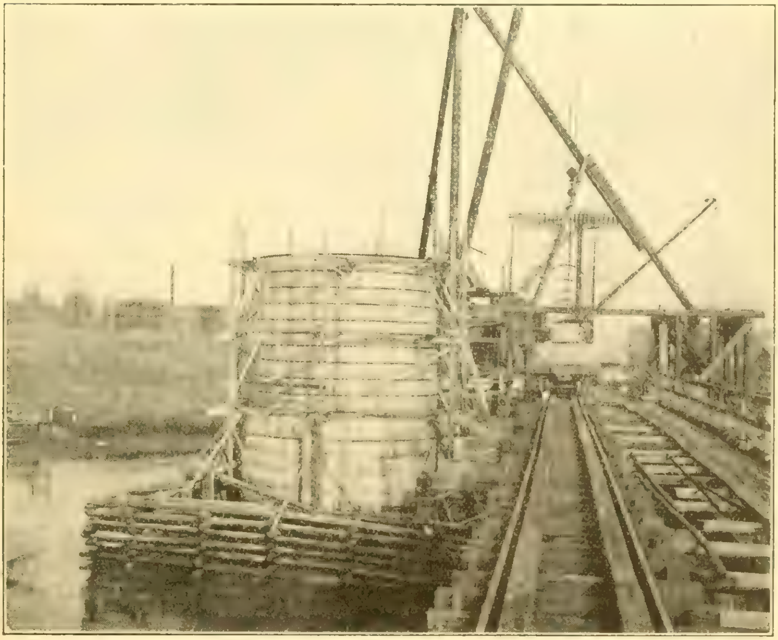
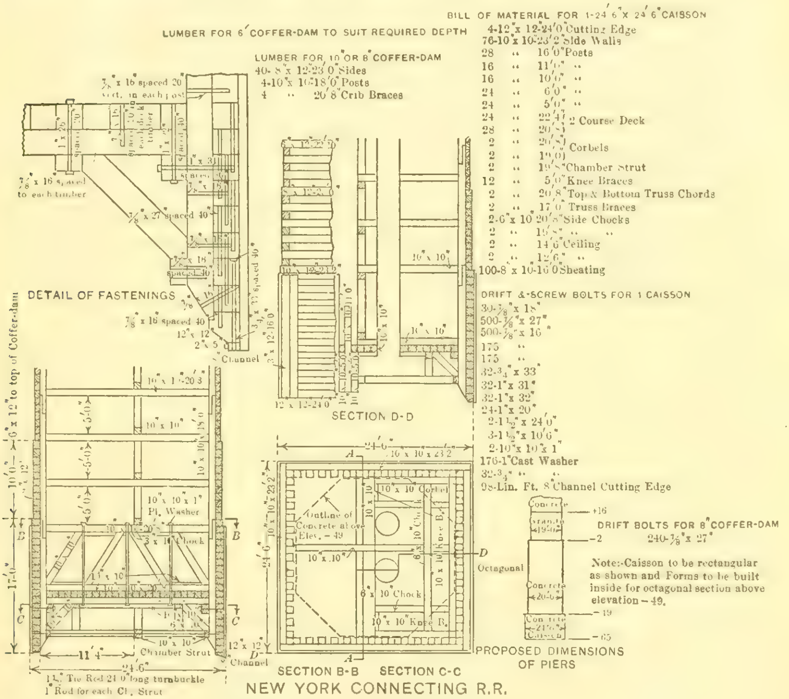


FIG. 65.—PIERS FOR LITTLE HELL GATE BRIDGE PROTECTED BY HEAVY CRIB

removing these arch centers, and, on a repetition of the work, a modification would probably be devised by which the form could be hinged at the top, and thus made collapsible. Mr. Seaman.

Owing to the great weight of the forms, a special crab-derrick was placed on top of the concrete and raised as the pier progressed.

Figs. 62 and 63 show the general arrangement of this work on Randalls Island and Long Island, respectively.



NEW YORK CONNECTING R.R.
PNEUMATIC CAISSON AND COFFER-DAM
FOR PIERS 20 & 21
BRONX KILLS BRIDGE

FIG. 66.

Fig. 64 shows the construction of the forms and centers for the piers of Little Hell Gate Bridge. The forms are practically hooped barrels, the first form being of variable height, as already described for the rectangular piers.

The foundations of these piers are on rock, about 12 ft. below low water, and in a current running 7 miles per hour. The construction was protected by heavy crib coffer-dams (Fig. 65). The pit was pumped dry and the bottom leveled off. Forms were then set inside for the concrete. On this concrete foundation, masonry was laid, about 12 ft.

Mr. Seaman. high, so as to protect the pier at the water surface. On this masonry the concrete shafts were then constructed. A trestle of simple pile construction, three piles per bent, with 12 by 12-in. caps and 12 by 12-in. stringers, was used at this river work.

The construction of the tower of the Wards Island foundation for the main arch span has already been described by Mr. Ammann. The preliminary studies of this work on the part of the contractor contemplated sinking these various cylindrical and rectangular concrete caissons by open dredging. This process proceeded with eminent satisfaction as to accuracy to a depth of about 30 ft. below ground, when it was believed by the engineers that greater progress could be accomplished by the use of compressed air. As such work, however, had not been contemplated by the contractor, it was taken over by the Railroad Company.

The foundations of the Bronx Kill Bridge were sub-contracted to the Arthur McMullen Company. Fig. 66 shows the caissons used by that firm. The deepest part of the foundations for these piers was 91 ft. below high water.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications.

THE ACTIVITIES OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS DURING THE PAST TWENTY-FIVE YEARS

Discussion.*

By Richard B. Smith, Jun. Am. Soc. C. E.

Mr. Smith.

Richard B. Smith,† Jun. Am. Soc. C. E. (by letter).‡—The very interesting "Appendix B" printed in connection with this paper will prove suggestive to many engineers who are concerned with the problem of systematically classifying and filing engineering data or literature. The subdivisions of civil engineering subjects are logical, and are evidently the result of much thought and experience. There are, however, a few questionable innovations in this proposed classification by subjects which should not go unchallenged, and it is worthy of careful study before being adopted as a standard.

The principal objectionable feature is the system of numbering. The range of numbers is so great as to make them practically worthless as mnemonic symbols representing certain subjects. Another innovation of doubtful value is the abandonment of the Dewey "form subdivision" and the substitution therefor of one having less clearly defined limits and scope for its various subdivisions. Dewey gives the following as a general classification for any engineering subject:

.01 Statistics,
.02 Quantities and costs,
.03 Contracts and specifications,
.04 Designs and drawings,
.05 Executive,
.06 Working and maintenance,
.07 Laws and regulations,
.08 Patents,
.09 Reports.

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* This discussion (of the paper by Chas. Warren Hunt, M. Am. Soc. C. E., published in December, 1917, *Proceedings,* and presented at the meeting of December 5th, 1917), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Superior, Nebr.

‡ Received by the Secretary, February 13th, 1918.

Mr. Smith.

He gives the following classification for any subject in general:

.1 Theory and philosophy. Bibliography.
.2 Handbooks, compends, outlines, etc.
.3 Dictionaries, encyclopædias, etc.
.4 Essays.
.5 Periodicals.
.6 Societies, transactions, reports, etc.
.7 Education.
.8 Polygraphy (collections). Inventions (expedients, etc., for engineering).
.9 History.

The writer would prefer to see these headings retained, together with their corresponding numbers (to serve as mnemonic symbols), and would prefer also to see the numbering and arrangement of subjects made to conform more closely to the Dewey system. For example, structural engineering foundations, retaining walls, bridges, and building construction might be developed as a subdivision of the Dewey number 624; and the subjects of surveying and drawing might be placed under his number 620 "Engineering in General". Also, the subjects navigation, shipping, and shipbuilding should be divorced from the heading "Military and Naval Science"; they could be given a co-ordinate heading under the Dewey number 629.

The writer questions the "utility" of classifying water-wheels (turbines, etc.) under "Water Power" rather than under "Hydraulic Machinery" or locomotives under "Railroads" rather than under "Mechanical Engineering". Railroads make use of many branches of engineering, so why not put such subjects in their own respective classes, thus securing a more detailed classification?

The heading entitled "Gas Engineering" could be divided between "Mining Engineering" and "Chemical Technology"; otherwise, we might as well have a heading for "Oil Engineering" and for several other large industries which Dewey classifies under "Chemic Technology" and "Manufactures".

The writer is glad to see the engineering subjects classified by Dewey under "Building" placed in their true relation to engineering subjects; the Dewey subjects of "Building" might well be left to include only the building trades.

The Dewey system, with all its defects, has proved fairly satisfactory for library classification, and has been widely adopted. The main Dewey numbers are easily remembered, and serve a useful purpose as symbols. The Civil Engineering Profession would do well to classify its literature and data in as close conformity as practicable with the system most generally in vogue, with due regard to its relation to that of other professions and to literature in general.

The writer has had a great deal of respect for the Dewey "Decimal System" ever since it first came to his notice. It is nothing less than a systematic classification of all human knowledge, and ought to be more generally familiar to engineers.

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PAPERS AND DISCUSSIONS

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ICE DIVERSION, HYDRAULIC MODELS, AND HYDRAULIC SIMILARITY

Discussion.*

By Messrs. J. Waldo Smith, Robert Fletcher, and A. F. Parker.

J. Waldo Smith,† M. Am. Soc. C. E.—It does not seem that the point made by Mr. Groat as to the efficiency and value of small models in solving hydraulic problems can be emphasized too strongly. It is truly surprising how nearly the results indicated by his models were verified by subsequent actual experience. The results obtained on small models are usually to be considered as being indicative rather than absolute, and this is especially the case in new fields of hydraulic construction where we have to deal with what may be called excessive head, quantity, or velocity. In such situations the search must be for a guiding experience which will tend to indicate all possible limitations as to structural dimensions, and as to the factors of flow, of velocity, and of turbulence in the passing water. Mr. Smith.

With these ends in view, a model was constructed in connection with the design of the spillway and channel of the Boonton Dam, at Boonton, N. J. The line of the spillway channel was at a very acute angle with the axis of the overfall section, so that when the water had passed into the channel, after a fall of 50 ft., its velocity would have been very high. Such a condition would have called for a high and massive retaining wall, in order to keep the waters within the channel section. This problem was solved by constructing a model and by studying the behavior of the water when passing over it. As a result

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* Discussion of the paper by Benjamin F. Groat, M. Am. Soc. C. E., continued from February, 1918, *Proceedings*.

† New York City.

Mr. Smith. of these studies, a steep chute was constructed at one end of the spillway section, so that the water passing down it would acquire a high velocity parallel with the axis of the overfall, and thus by its weight and volume cause the resultant between it and the volume of the overflowing water to coincide with the axis of the channel.

At the present time, the general plans of the new overflow dam on the Schoharie development of the Catskill water system are being studied, and there will be built a good sized model of the dam and spillway before deciding on the various structural details involved. Here the dam is to be at right angles to the stream bed. The water will pass over its crest for a length of 1 300 ft., all on one side of the valley. The fall will vary from 160 ft. at one end, decreasing up the side of the valley to about 20 ft. The down-stream face of the dam is to be formed in large steps, from 10 to 20 ft. in height and from 10 to 18 ft. in width. The water will finally fall into a spillway channel along the toe of the dam, the bottom of the channel having a steep grade to the present stream bed. A high wing-wall will be built along the far side of the original stream bed, nearly at right angles to the dam and also at right angles to the axis of the spillway channel. It is expected that the model will give much information as to the action and behavior of the water and in determining many details as to the structural design, with particular reference to any features which may be needed in order to guide and control the direction of flow.

The author's reference to the skimming process recalls to the speaker's mind one of the best examples of this process which he has seen. At Omaha, Nebr., the very turbid Missouri River water was pumped into a settling reservoir, composed of a series of basins about 30 ft. deep. The water paused in these basins and then successively passed over long weirs separating the basins. The sediment settled quite rapidly, so that the thin skin passing over the last weir was, when seen, quite clear—for water of such character—and reasonably satisfactory for use without coagulation or filtration.

Mr. Fletcher. ROBERT FLETCHER,* M. AM. SOC. C. E. (by letter).†—The author has made a very positive and questionable statement on the "Performance of Models" in the following words:

> "His conclusion concerning this matter is that models perform in much the same way as the full-size prototype. In fact, there was nothing in the results of the experiments to indicate that they did not perform exactly as their prototypes. These statements apply equally to hydraulic models of all kinds, whether they be of machines, such as water-wheels and pumps; of structures, such as overflow dams, weirs, and spillways; of sections of an actual river or canal; or of ships."

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* Hanover, N. H.

† Received by the Secretary, January 24th, 1918.

Mr. Fletcher.

The inexorable laws of Mechanics forbid any such sweeping general conclusions. William M. Torrance, M. Am. Soc. C. E., has made a convincing exposition of this question in an article* entitled "Use of Models in Engineering Design," and has warned his readers against misconception of the value of such models in practical applications. Having made a model of a concrete water tank on a concrete trestle tower to a scale of 1: 30 he showed that the model was proportionately stronger than its prototype of full size, inversely as the scale, or thirty times as strong. The apparently surprising strength and agility of diminutive creatures, like frogs, fleas, etc., in leaping power, was shown not to be remarkable, because the proportionate strength of their limbs, being as their cross-sections, are as the square of the linear scale of their size, though the weights are inversely as the cube of the scale; hence their relative muscular power is as the scale of their dimensions. Therefore, a frog or a flea can leap as far as a man can jump, because he has relatively more strength in proportion to his weight.

Commenting on this article, the writer added, among others, the following examples:

Passing from statical conditions to dynamical the following examples are to the point:

"Before the elevated railway was built in Boston the late Capt. J. V. Meigs made strenuous efforts to have his single-truss elevated railway adopted. The track or 'way' or truss was provided with two bearing rails for the horizontal wheels and two lower rails for the diagonal wheels of a unique form of truck, and the truss was supported on a single line of columns, as in the first New York elevated railway. This is fully described in Vol. VII, *Transactions,* Am. Soc. M. E., paper No. 189. An expensive working model was set up in a large upper room of a warehouse in East Cambridge, Mass., where the inventor demonstrated the 'successful working' of his scheme to visitors, as he did to the writer and a class of students in November, 1885.

"The model engine weighed 275 lb., the tender 80 lb., with a model car six feet long. Steam was 'gotten up' quickly and the train developed an average speed of 10½ ft. per second, passing curves of 6¼ ft. radius and mounting grades equivalent to 610 ft. per mile (adhesion increased by accumulator pressure on the horizontal truck wheels). On level track a speed of 22 ft. per sec. was made.

"This performance doubtless convinced the most skeptical; but on this occasion the spectators were reminded that the forces in action, especially the centrifugal reaction [not force, but the opposing effect of inertia as the body is incessantly pushed by the curving rail toward the center] on the curves, would be vastly out of proportion to the scale, in the full-sized train. The model was made on a one-eighth

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* *Engineering News,* December 18th, 1913.

† *Engineering News,* January 29th, 1914.

Mr. Fletcher. scale, and, if W represents the weight and v the velocity of the model, this centrifugal reaction would be expressed by $\frac{W}{g} \times \frac{v^2}{r}$. Assuming a velocity in the same proportion, one-eighth of, say, 66 ft. per sec. (45 mi. per hr.) = 8¼ ft. per sec., and radius r of curve in like ratio, then, since W of the large engine will be as the cube of the scale, we have the action of the actual engine measured by $\frac{(8)^3 W}{g} \times \frac{(8)^2 v}{8r}$ $= 4\,096 \frac{W}{g} \times \frac{v^2}{r}$. To resist this the strength of track-frame, trusses, columns, etc., which depends upon the cross-sections, would be in the ratio of $(8)^2 = 64$ to 1: and the disproportionate dynamic effect of the full-sized engine would be $4\,096 \div 64 = 64$ times greater than any which the model could exert. The numerical measure of the larger effect would be, on a curve of 6¼ × 8 ft. radius: $4\,096 \times \frac{275}{32} \times \frac{8\frac{1}{4}\ 8\frac{1}{4}}{6\frac{1}{4}}$ = 384 000 lb. This is 2.7 times the weight of the machine (275×8^3 = 140 800 lb.); but it will be noticed that the radius is quite short and the speed (66 ft. per sec.) for so sharp a curve is not permissible. Right here is where the uninstructed experimenter is deceived if he infers proportionate dynamical stability from the beautiful behavior of the model.

"A different case is that of an experimental model dam. In a discussion we usually consider only a unit of length, say 1 ft. Assume a model 2 ft. high with any acceptable cross-section, to represent by a one-ninth scale a proposed dam 18 ft. high. Here relative *statical* effects depend upon the hydrostatic law that the [total] pressure varies as the square of the depth $\left(w \times h \times \frac{h}{2} = \frac{w\,h^2}{2} : w \times 9\,h \times \frac{9\,h}{2} = 81 \frac{w\,h^2}{2}\right)$. But the similar cross-sections also vary as the square of the scale; and all pressures and resultants in the two cases hold the same relative position. Hence, this is a case where the full-sized dam really has stability proportionate to that of the model.

"This condition, however, is far from true when overflow occurs. For instance, assume 6 in. gage depth of flow over the model, which would represent 54 in. over the proposed crest. Now the hydrodynamic law of discharge over weirs is (the quantity) $Q = c\,l\,h^{\frac{3}{2}}$, in which c is a constant, l the length and h the gage height above the crest; and $(9)^{\frac{3}{2}} = 27$. Here, then, the discharge over the full-sized dam would be 27 times that over the model; and, more than that, *it has nine times as far to fall* (really 9½, from the center of gravity of the overfall). The energy acquired, which measures its capacity for destruction, varies with the height of fall and is, therefore, $9 \times 27 = 243$ times that of the water discharged over the model dam.

"Considering this inexorable mechanical law the designer may anticipate in some degree the tremendous impact against the backwater below, the scour on the bed of the channel, the 'kick-back' or reaction against the apron and toe of the dam, the vacuum effect

Mr. Fletcher.

upon the dam itself, etc.; but these would not be even faintly suggested by the behavior of the model and its 6-in. overflow."

It may be objected to this discussion that we have assumed 1 ft. in length, both for the actual dam and its model; whereas we should make the comparison by using only $\frac{1}{9}$ ft. of the model; and that, therefore, gives only 27 to 1; or, the relative effects are as the $\frac{3}{2}$ power of the scale ratio; but that is just where we are deceived. It is true that the total effect of shock and destruction along a line only one-ninth as long in the model as in the dam is only as 1 to 27; but the destructive effect will not be confined to a proportionate length. The convenient unit of 1 cu. ft. of water and 1 lin. ft. in both cases is proper, because it is required to compare the energy, symbolized by Wh (of the model), with that of $W' h'$ of the real conditions; that is, Wh compared to $27\ W\ 9\ h$; or, to state it otherwise, we are concerned here to compare the shock or destruction per foot or other equal length.

In a recent work,* J. L. Van Ornum, M. Am. Soc. C. E., gives an interesting account of some elaborate experiments made by German engineers at the Experimenting Establishment in Berlin. These are right to the point in this discussion. The problem and plan of procedure are stated thus:

"Because of uncertainties with regard to the attainment of entire success in being able to definitely represent on a small-scale model all the conditions of a natural river and to be assured that the effects of artificial modifications in the streams are correctly indicated by corresponding changes of the model, it was decided that the first requirement was the true reproduction of a definite part of the natural Weser River, and then to compare the effects of flowing water upon it with the state of the river bed which had been produced by corresponding conditions. If this experimental verification of the correctness of the details of reduction in scale and choice of materials proved satisfactory, then it could be confidently assumed that experimental investigation of the effect of any proposed plan or detail of regulating works would show, on the model, the consequences that would result from the same construction of full size in the river itself. For this purpose a portion of the Weser, 1.6 km. in length * * * was chosen because of its availability in its definitely known characteristics both in its natural state and after works of improvement had been installed, the stability of its bed in showing similar conditions to exist at each recurring low water stage, and because a more effective regulation of that stretch of river was desired.

"The condition of the facilities of the hydraulic laboratories caused the adoption of a scale of linear reduction of 1 to 100 for both horizontal and vertical dimensions. With regard to the character of material which should be used for the bed of the artificial stream, it was

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* "The Regulation of Rivers", pp. 163 to 172.

Mr. Fletcher. evident that a variation in size corresponding to that of the river itself is important; but the question of the suitable proportionate size was not so clear. It was said that apparently the ratio of volumetric reduction should be as 1 to 100, which would call for an average diameter of grain of about 1.7 mm. inasmuch as that of the river gravel was about 8 mm. However, after some investigations of the behavior of graded sand of various average sizes under the action of flowing water, * * * a river sand of an average diameter of about 1.2 mm. was chosen for the material of the model; this was, in later experiments, changed to 1 mm., or six-tenths the diameter which would keep the volumetric ratio of the particles the same as the linear ratio of reduction for the general dimensions of the model."

So, to begin with, a scale reduction was made, reducing the size of particles to be transported to only 0.6 of that required by the geometrical relations. Then the account goes on to state that four other requirements had to be satisfied, *viz.:*

"A correspondence in relative height of mean low water, mean high water and mean water levels, the range in the model of course being one one-hundredth that observed in the Weser; all these water levels are to have a similar corresponding relation with respect to the tops of the groynes; the depths and cross-sections of the three water levels must have a like relation to those of the natural river; and the discharge in the model is to have a constant ratio to that of the Weser at all three stages mentioned".

It was considered that the continued product of the slope, depth, and reciprocal of the diameter of the grain should have the same value in both the model and the river. For the river this product was 0.0000235 and for the model 0.021; but we learn that:

"Repeated experimental attempts to attain satisfactory results on the basis of that computed slope seem to have proved disappointing; at any rate a slope of about one-tenth that value and a ratio of unit discharge of 1:40000 were experimentally found more satisfactory. Later, a surface slope of about 0.0015 and a corresponding discharge ratio of 1:50000 were found to produce a channel in the model still more nearly coincident with that of the river itself, especially for the higher stages."

So here, again, preliminary trials led to very considerable changes in the computed quantities. Then, in conducting experiments, the bank protection and controlling groynes in the model were made with "small sacks of shot", and "small pieces of slate, at slopes of 1 on 1." It would appear that the density and stability of such materials are almost as much out of proportion to the resisting qualities of the materials on the actual river as would be steel sheet-piling *vs.* brush mattresses and rip-rap. Erosion in the model was prevented or corrected by these bags of shot.

Mr. Fletcher.

Although some interesting similarities in effects were found, on comparing the profiles and cross-sections of the model and the river, it was admitted that there is

"A lack of coincidence in details which suggests the conclusion that the system is not yet perfected. Such irregularities are found as differences in distribution of shallow and deep portions of the channel, the smaller depths in the reach shown by the model, the greater variability in the experimental depths, and especially the greater comparative depths in the concave banks. While the last-mentioned difference is not important with regard to the effect upon navigability, it is, nevertheless, one of the characteristics by which the question of the adequacy of experimental methods must be judged."

Following the statement quoted at the opening of this discussion, Mr. Groat makes the following further positive statement:

"In the case of hydraulic models, it can be shown that homologous velocities in models of different size must be proportional to the square roots of homologous linear dimensions. When the quantities of water have been properly adjusted to comply with this requisite, it may be said that the mechanical and hydraulic conditions in the two models are mechanically and hydraulically similar, just as the configurations of fluids and solids in the models are geometrically similar."

He then states that experimenters with water-wheels have overlooked these relations and conditions, and have failed to make proper tests of model wheels.

Now the writer thinks that the instances cited by Mr. Torrance and himself plainly refute the idea of simple and always uniform interrelations and analogies. It is shown that, in a model of a static structure, additional load must be supplied to the extent of the weight of the model multiplied by the scale ratio. (A model bridge made by the writer had to be loaded with 350 lb. before the individual members were stressed in proportion to the homologous stresses in the bridge represented.)

In the single case of the model dam, as the pressure (load) itself varies as the square of the depth, the behavior of the model and its prototype are the same; but in all cases where dynamic effects are involved, we cannot usually make the model and its prototype comparable or analogous by simple adjustments or contrivances.

Referring now to the experiments conducted by Mr. Groat, the writer would not presume to criticize the procedure or question the validity of the conclusions, so far as they relate to the particular object sought, and strictly under the conditions stated. No doubt, as the German experimenters found, useful lessons may be learned from "model" performances, but only under very special and tractable conditions. We have seen how their protracted and painstaking endeavors

Mr. Fletcher.

resulted in admitted failure to gain the full result sought. For one thing, changes in the model or miniature could be made with ease; but similar modifications under actual conditions might involve great labor and expense or develop unexpected forbidding conditions which the mere model would not suggest. (Like a plan "on paper" *vs.* a procedure necessitated in face of the working conditions.)

Engineers familiar with our northern rivers, even those flowing from north to south, and thus under more favorable conditions for getting rid of ice in the spring, know too well some of the extreme conditions that defy calculation. Although pieces of paraffin in a small stream may simulate ice carried under ordinary conditions of moderately high water, they are essentially different from ice. They will not freeze together as will ice after a thaw followed by a "cold snap"; they would not readily be subjected to the great side pressure which drives ice laterally into side channels and high up on sleeping banks; they would not so easily simulate the great jams which fill the entire channel, pile up high above it, and cause an excessive rise of the river, leading to destruction of dams, mill buildings, etc.; neither would the miniature contrivance be likely to produce baffling conditions of back-water which vex the souls of those who operate power plants. The writer's observations and experience on a river like the Upper Connecticut is that artificial furrows or transverse ridges in the bed of the river would be speedily obliterated in whole or in part, either by erosion or filling up; and such aids as jetties for controlling the flow, as proposed, must needs be of expensive construction to be permanent, and may easily be overtopped by high floods. The following instances illustrating the above stated points are only a few among many which might be cited.

At Sumner's Falls a rocky barrier extends so obliquely across the river that its length is nearly double the direct width of the river. About 50 years ago at this site there was a dam, a canal lock and approach canal for river boats, and a very large saw-mill running seven saws. A spring flood brought down ice which jammed and froze; a second flood increased the jam, piled the ice high on the dam and against the banks, and finally carried the mill down stream, and wrecked the dam and lock, which were never rebuilt. The writer has seen* an impressive picture of blocks of ice up to 4 ft. thick (a man standing beside one) wedged together over an extent of many acres, on one side of the Lower Yellowstone dam, in Montana, as the result of a high flood. This suggests in part the possibilities of destruction by a spring flood carrying ice.

At the Vernon dam and power-house the spillway is 650 ft. long, and the fall, without flash-boards, is 32 ft. The river just below

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* *Engineering News,* November 14th, 1912, p. 893.

Mr. Fletcher.

widens to 1 200 ft., but below that is a short curved narrows, about 400 ft. wide. Yet the engineer reports that in a high flood the water below the dam has risen to within 0.8 ft. of the crest, so as to make it for a time practically a submerged dam. How could any model dam and section of this bay and gorge, extending actually a mile on the concave, have suggested this condition of back-water?

When we consider the demonstrated fact that the transporting power of a stream varies as the sixth power of the velocity; that the energy of the flowing water varies as the cube of the velocity; and know that, by geometrical necessity, any model on a reduced scale lacks weight and stability in itself to test its full capacity, under diminutive conditions, we are obliged to object to the quoted all-inclusive claim for the validity of model studies and experiment, especially where hydrodynamic operations are involved.

Mr. Parker.

A. F. Parker,* M. Am. Soc. C. E. (by letter).†—The writer has been actively interested in the problem of canal intakes and keeping them clear. This paper mentions only the matter of ice and floating materials, and in large streams, presumably of not very great fall. Under conditions of ice flowing in such large rivers, and with only moderate velocity, the sub-diversion channels described may produce very good results; but, in smaller streams, of heavy fall, such as are usually found in mountainous districts, it is not so evident that the method presented would produce the results sought. In mountain streams it is usually necessary to build a diversion dam at each intake. Sometimes such dams may be permanent, and in other cases movable dams are necessary in order to pass the annual spring floods. In the case of a permanent dam, the basin back of it always fills up with silt, sand, and sometimes heavier drift materials, so that in time there is only a limited space of any considerable depth at the intake. Movable dams are erected only at low-water stages, and, when removed to pass the spring floods, the current sweeps the deposits accumulated in the basin cleanly away. Thus the action resulting from the use of either form of dam would evidently preclude the use of sub-diversion channels.

In such cases—and such conditions obtain almost everywhere in mountainous localities—it is always very difficult to keep intakes clear of ice. The main reliance must be placed on drawing the water from the greatest depth possible below the surface. The still water above the dam holds the ice flow, but sometimes the mush ice reaches nearly the full depth of the water. Usually, a large gang of men is required to keep the intake clear, and it is impossible to prevent considerable quantities of ice from entering it.

In streams of the kind mentioned, however, the ice problem is not the only one involved in intakes, for it is equally difficult to contend

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* Ogden, Utah.

† Received by the Secretary, February 14th, 1918.

Mr. Parker. with sand, gravel, and floating and submerged driftwood. During high water driftwood lodges against trash racks, as commonly placed, finer materials are then caught, and, with sand and silt, often make an almost water-tight dam; sometimes it is as difficult to keep such racks clear, as when there are ice formations. Sand and gravel, washing into intakes and thence down the canal or pipe line, cause much damage to water-wheels, or they clog the canal and are not easily prevented. It is evident that sub-diversion channels are likely to be easily filled in by the river drift in times of high water, even in large slowly moving streams; it is absolutely sure that the swiftly flowing streams common to the mountains would either fill them up or that they would serve to divert the sand and gravel—carried in great quantities by the torrential flows—into the intake; a condition it is desirable to avoid.

Perhaps it is unfair to discuss conditions differing so much from those assumed in the paper, as do the usual mountain streams, but the excuse is in the great interest and importance of the matter under all conditions. The writer submits plans (Fig. 7) showing an intake designed for an irrigation and power canal, where it was very difficult to deal with the ice in winter and the floating drift, sand, and gravel in summer. This intake was not built just as shown on the plans, and does not now give the best results. Had it been built as designed, it would surely have done the work in the best possible manner.

The plans show a movable dam across the stream, operated from a service bridge above it. In place of the usual trash rack, there is a vertical diaphragm of wood fastened to steel beams extending between undercut concrete piers and reaching in a straight line up and down stream and nearly parallel to it. This diaphragm is set above the middle of a concrete channel, with side-walls flush with the bottom of the river. The water is discharged below the dam, the flow through the concrete channel being controlled by a wooden gate. The diaphragm wards off all floating materials, and the space under it allows the water to pass to the intake. The channel or trough of concrete catches all sand and gravel washed down by the current, and the rush of the current of water through it removes all such material and prevents clogging; the channel has been given a heavy fall in order to accomplish this.

Below the diaphragm, and some distance away, there are two Tainter gates, each 18 ft. wide and 13 ft. high. Between the gates and the diaphragm, and on the river side, there are five wooden gates which serve as relief gates for the pool of water that the Tainter gates may be made to form. In the bottom, and leading to these five gates, there are some channels extending diagonally across and below the floor of the intake, and these catch and remove the sand which passes the diaphragm channel; the pool above the Tainter gates acts in some degree

Mr. Parker.

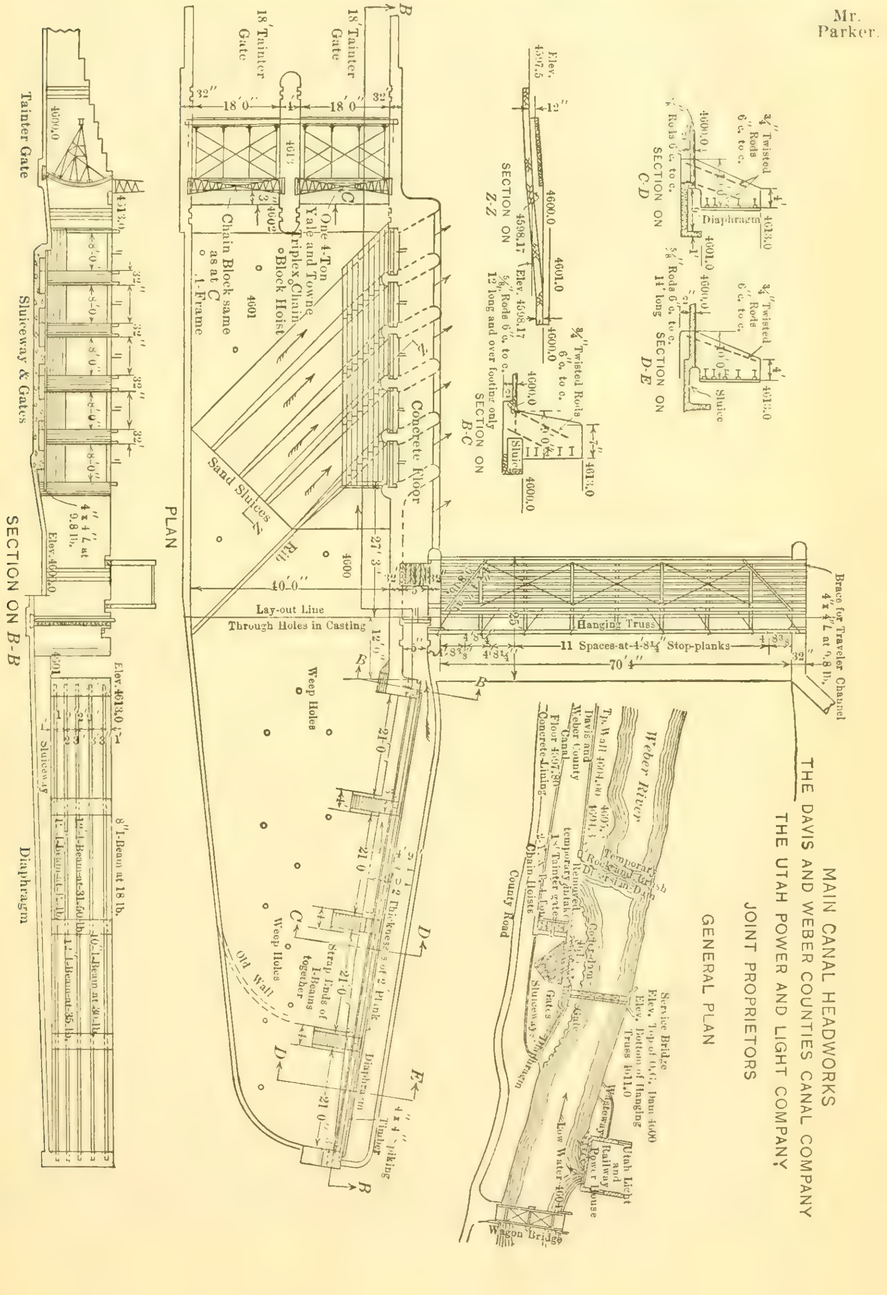

FIG. 7.

Mr. Parker. as a settling basin. The five wooden gates serve not only to close the side of the channel and provide an overflow, but are arranged so as to operate the sand trap, being left up a short distance when there is water enough to waste, or are raised occasionally for flushing out the sand.

The arrangements to care for all conditions of flood or frost, and to remove the sand and gravel entering the intake are complete, and, provided there is sufficient fall to the location, cannot fail to do good work. The arrangement would need modification where the fall is light, but the general idea could be preserved. From the plans the design may be easily understood. Is it not reasonable to regard a deflecting diaphragm, as shown here, with a sub-surface intake entry, as promising better results under all conditions, and more logical to adopt in place of the usual rack so easily clogged either by trash or ice?

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PAPERS AND DISCUSSIONS

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MANHATTAN ELEVATED RAILWAY IMPROVEMENTS

Discussion*

By Messrs. Clarence E. Carpenter, George H. Pegram, T. Kennard Thomson, Edward Wegmann, and Howard Constable.

Mr. Carpenter.

Clarence E. Carpenter,† Assoc. M. Am. Soc. C. E.—The authors of this paper are entitled to the thanks of the Profession for having prepared and presented a detailed and complete description of one of the most difficult and extensive traction developments ever carried out in New York City. The work was divided into sixteen sections, according to location on the several elevated lines. Each section presented, to a greater or less extent, distinctive problems calling for a special design and method of procedure. The paper, therefore, is of considerable value for reference to engineers who may be called on to execute work of this character.

The speaker's connection with the work was practically limited to the maintenance and operation of the elevated lines during its progress and after completion. Detailed plans and specifications for track construction were prepared by the Maintenance of Way Department of the railway company.

The greater part of the track material was loaded on work trains at the storage yards and distributed along the right of way by that Department. All track work, within the clearance lines of tracks under operation, was performed by the company's maintenance force, and also all contact-rail work and accessories. All flagmen stationed on the tracks to prevent trains from running into obstructions or striking

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* This discussion (of the paper by F. W. Gardiner and S. Johannesson, Members, Am. Soc. C. E., published in December, 1917, *Proceedings,* and presented at the meeting of February 6th, 1918), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† New York City.

Mr. Carpenter.

employees were furnished from the same force. The flagmen did their work well, as on no occasion did a train encounter any obstruction or become derailed due to the track not being clear or in proper shape for operation. The Maintenance of Way Department furnished experienced ironworkers for the inspection of rivets, and inspectors who co-operated with the construction engineers in following up the contractor's excavating and shoring work to insure the stability of the structure and the safety of passengers. At times during the progress of the work as many as 150 men were employed as flagmen and rivet inspectors.

The work comprised the laying of approximately 24 miles of single track, of which 15 miles were new track added to the elevated system and 9 miles were old track rebuilt. About 6 500 tons of new steel rails and 12 000 000 ft., b. m. of new track ties were used.

It may be of interest to refer to a few of the important features of the track construction. All track rails on tangents, and on curves having a radius larger than 400 ft., were of open-hearth steel having the following chemical composition:

Carbon............0.75 to 0.90; average not less than 0.80;
Manganese.........0.60 to 0.90;
Silicon not more than 0.20;
Phosphorus not more than 0.04.

All rails on curves having a radius of 400 ft. and less, except in yards and emergency cross-overs, were of manganese steel. Steel guard-rails were placed on the inside rail of all curves of less than 2 000 ft. radius. The guard-rails were bolted to the track rails at intervals of 3 ft. with $\frac{15}{16}$-in. steel bolts, and were carried at least 60 ft. beyond the points of tangency of the curves. All rails on tangents through switches and special work, and on curves having a radius of 500 ft. or more, were laid true to gauge of 4 ft. 8½ in.; on curves between 500 and 150 ft. the gauge was widened to 4 ft. 8¾ in.; and on curves having a radius of less than 150 ft. the gauge was 4 ft. 9 in.

The replacement of the old Second Avenue-Harlem River Drawbridge with a new double-deck four-track drawbridge was perhaps the most conspicuous feature of the work. The bridge has two shore spans and one draw-span. The authors have described the replacement of the south shore span on February 22d, 1915, and of the north shore span on March 6th, 1915. The excessive variation in the range of the tide in the Harlem River caused some anxiety during both these operations. In the case of the removal of the old south shore span, the tide reached its highest level and the northeast corner of the span still rested on the pier. A derrick boat was used to lift that corner, and, fortunately, the span just swung clear of the piers. At the time the north shore span was replaced, the range of tide was nearly twice as great as when

Mr. Carpenter.

the south span was floated. The scows were placed under the old span and the blocking set up to lift it at 1 A. M., when arrangements had been made to suspend traffic on the bridge. The tide rose with great rapidity and began to lift the span, so that trains had to be flagged at both ends of the bridge at 12.44 A. M. Before the draw-span could be opened, the shore span rose so high that the lift-rails would not swing clear, and some very lively work was necessary in order to disconnect the tracks before damage resulted.

Mr. Pegram.

GEORGE H. PEGRAM,* PAST-PRESIDENT, AM. SOC. C. E.—This paper is so complete that the speaker did not expect to discuss it, but Mr. Kittredge has alluded to the co-ordination of forces in work of this kind, and it is proper to state that the co-ordination practiced was in line with what the different governments of the world are now finding to be more and more necessary: the centralization of power in one man.

After the preparation of the general plans, Mr. Gardiner was given, practically, a free hand in the preparation of detailed plans and in carrying out the work of the structural portions, and C. E. Carpenter, M. Am. Soc. C. E., Engineer of Maintenance of Way, was given similar freedom in the necessary track changes and extensions.

In viewing the work at the beginning it did not seem possible that it could be accomplished without accident. It certainly did not seem probable that it could be accomplished without more interruptions of traffic than occurred, and this was largely due to a centralization of power, which prevented confusion of orders.

The reference which Mr. Thomson has made to the ancient history of the structures is of interest. These old elevated railways are probably the oldest metal structures in the world in point of use, having been subjected, during the 40 years of their existence, to constant and rapidly repeated loads, in some cases exceeding those for which they were designed.

Great credit is due to the designers and builders who produced a structure which after 40 years could have a third track added without the entire replacement of the old work. There were many details in the old structure for which there was no precedent. The one requiring the greatest courage in design was the single-column structure. The designers probably did not anticipate that the swaying of the locomotives would cause a lateral thrust of 6 000 lb. at the top of each column; and they probably did not anticipate that the extensions of the station platforms would be supported on cantilevers from the columns, thus causing a bending moment.

Although some of these columns rest on sand, no undue or irregular settlement has occurred. The columns were inserted in sockets in a

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* New York City.

Mr. Pegram. cast-iron base, in which they were fixed with a "rust" joint. This detail has proved very effective, and could well be repeated in the future. There are a number of columns with closed section in which no corrosion has been found after their 40 years of service, which is proof that the old and persistent specification, that closed sections should not be used, is unwarranted. A closed section is the strongest one for a column. There is no reason for not using it more generally.

Of course, the circulation of air in the columns of the elevated road is prevented, but it might also be prevented in the columns of bridges.

The detail most criticized is the want of intersection of the web members of the lattice girders. This is a very crude detail, and was probably adopted because the material in the chord was supposed to be so excessive that it was not necessary to take care of the moments at the joints; but this proved wrong, and it was necessary to double-lattice the girders to relieve these moments.

Cast iron is used for the supports of the canopies of the platforms and stairways of the old elevated structure. This is a detail which could be followed with advantage, as the cast-iron column can be made smaller, more ornamental, and less dangerous through contact than one made of rolled shapes.

Mr. Thomson. T. KENNARD THOMSON,* M. AM. SOC. C. E.—This Society and the City of New York owe a very great debt of gratitude to the authors and to their Chief, George H. Pegram, Past-President, Am. Soc. C. E., Chief Engineer of the Interborough Rapid Transit Company, both for this comprehensive paper and for the marvelous success with which they replaced the old elevated structures.

The old elevated railroad was being loaded far beyond the expectations of the original builders, and was rapidly becoming absolutely unsafe.

The new structures are thoroughly substantial and up-to-date, and show many ingenious methods of overcoming unusual difficulties of design; only engineers can realize the great care and engineering skill which Mr. Pegram, Mr. Gardiner, and their staff exercised so well, but withal so quietly and unostentatiously, in overcoming these unprecedented difficulties. This achievement should be brought to the attention of the public.

The speaker hopes that Mr. Pegram will enhance this valuable paper with many historical and other remarks about the old elevated railroad.

Fig. 135, showing a proposed elevated railroad for New York City in 1833, or some 30 years prior to the building of any structure of that kind, may be of interest.

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* New York City.

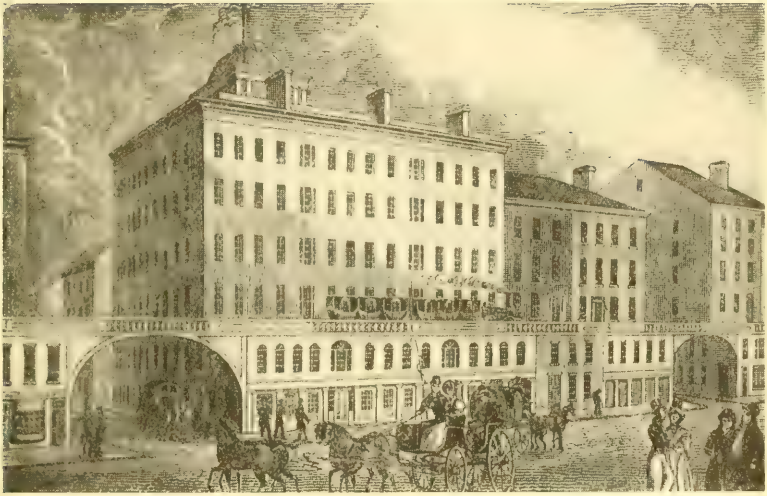

FIG. 135.—PROPOSED PLAN FOR ELEVATED RAILROAD IN NEW YORK CITY IN 1833.

Mr. Wegmann.

EDWARD WEGMANN,* M. AM. SOC. C. E.—The speaker wishes to compliment the authors on the excellent paper they have given the Society. It is so full of details, and involves so much complicated work, that it can only be discussed properly by an expert bridge engineer who is thoroughly familiar with the local conditions.

As the authors have made a brief reference to the early history of the elevated railways of New York, the speaker, who was connected for two years with the construction of the original structures, will say a few words about that work which may be of interest.

The construction of the Metropolitan Elevated Railway of New York—known originally as the Gilbert Elevated Railroad—was begun in the fall of 1877. The contracts for building this road from Rector Street to 42d Street, on Church Street, West Broadway, South Fifth Avenue, and Sixth Avenue, were let, about November 1st, 1877, to the Phœnixville Bridge Company, the Keystone Bridge Company, and the Edgemoor Bridge Company.

Each of these companies agreed to complete its part of the railroad within 4 months, and to pay a penalty of $1 000 per day for any additional time that might be required.

As a matter of fact, the railroad was built from Rector Street to 42d Street—a distance of about 3 miles—in 4½ months. On account of the difficulties encountered, the penalty for the 2 weeks of extra time was not enforced. Considering the fact that the iron had to be rolled in Pennsylvania, and brought to New York in winter, the speed in construction was remarkable, and could scarcely be surpassed at the present time.

The piers for the columns to support the structure were located from a base-line established on the west sidewalk, about 2 ft. from the curb. This line was measured with the utmost accuracy with a 25-ft., trussed, wooden, measuring rod, the length of which was compared from time to time with a standard rod, furnished by the bridge companies.

It was very difficult to establish a straight base-line on the crowded city sidewalks, especially on Sixth Avenue near 23d Street, which was then the great shopping district of New York. The speaker tried to run the base-line in the early morning, but found the weather too foggy, and finally resorted to the "pusher system". A member of the engineer corps or a laborer was stationed on each block. At a given signal, these men would push the crowd to one side, with loud shouts, and before the people had time to discover what caused the commotion, the line had been sighted. If the speaker had to do this troublesome kind of surveying again, he would order tripods of extra height, to enable the transitman to sight over the heads of the people by standing on a box.

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* New York City.

Mr. Wegmann. As regards the wooden measuring rod, a 50-ft. spring-balance tape would have expedited the work, and would have been sufficiently accurate. The engineers engaged on those early elevated railways were very much impressed with the accuracy that was required, to insure that the ironwork would fit properly together. To show that this anxiety was somewhat unnecessary, the speaker will mention what happened to one column of the Sixth Avenue structure. In setting the templates for the anchor-bolts of the piers, the engineers measured, with a wooden rod, 23.5 ft. from the base-line to the center of the west pier, and then 23 ft. to the east pier. In setting the template for one of the piers, the engineer used the wrong mark on the measuring rod and placed the pier 6 in. too far east. When the ironwork was erected, the column on this pier was riveted to the cross-girder, and neither the workmen nor the engineer found out for some time that it was 6 in. out of plumb. The error was corrected by using a special base casting, which brought the center of the column into its required position.

The piers supporting the columns were built of brick, founded on large stones to which the anchor-bolts were fastened. The ordinary depth of each foundation was 10 ft., but, at the street intersections, where columns had to be built, according to the charter, the foundation depth was usually about 30 ft., in order to get down to the bottom of the street sewer, over which arches were generally built. Water and gas mains, etc., were usually straddled with I-beams, well protected by cement mortar.

On Sixth Avenue about ten piers were built daily on each section of the work. On the Second Avenue line, erected about a year later, about fifteen piers per day were built on each section. It required quick work on the part of the engineers, to give line and grade for the piers and to keep memoranda of how all the obstructions were bridged over. Very frequently the special plans for the piers, made at headquarters, arrived after the piers had been built, and all that the field engineer could do was to certify that the plans looked very much like the piers actually built.

The contract for the Sixth Avenue Elevated Railway was let by the Metropolitan Elevated Railway to the New York Loan and Improvement Company at $1 000 000 per mile. As engineer for the Keystone Bridge Company, the speaker knew the actual cost of the Sixth Avenue structures, which amounted only to about $500 000 per mile, including stations and track.

The Third Avenue Elevated Railway—which was a lighter structure than that on Sixth Avenue—cost only $325 000 per mile, according to figures published in technical papers at the time.

Mr Constable. HOWARD CONSTABLE,* M. AM. SOC. C. E.—Mr. Pegram has spoken of closed columns as possibly being worthy of attention. In 1883 the

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* Kingston, Mass.

Mr. Constable. speaker made, for the late Octave Chanute, Past-President, Am. Soc. C. E., a report on the Interior Rusting of Wrought-Iron Columns. Many structures, in the East and Middle West, from 10 to 40 years old, were visited. A concave mirror with a small hole in the center was used to throw light up into the interior of a column, if open at the bottom, or through a 1½ or 2-in. hole, specially cut out, as near connections as possible.

In the case of the Omaha Bridge, there were a great many open columns, the interior of which could be easily inspected for a distance of about 6 ft. when the speaker was suspended from the lower chord of the bridge. The paint was mostly intact, and there were only occasional flakes of rust. In the case of a double webbed girder at Phœnixville, Pa., which was brought from England about 1840, the red lead paint in the interior was still slightly soft. No case was found where the interior rusting exceeded 0.5% of the cross-section. Some heavy rusting was found where columns were set in a cup-like shoe or base, also where lattice straps on the outside were not in full contact and left a capillary space for the retention of moisture.

The observation openings were made by first drilling a ⅜-in. hole, then using a special tool, somewhat like a washer cutter. The washer or disk with its hole, was kept as a sample, and the hole in the column was tapped and a plug screwed into place.

The speaker was so well satisfied that interior rusting was not as serious as had been claimed, that in later years he designed and erected a 6-story factory in which compressed air was taken up all the columns and used as required for smelting, sand blast, etc., by removing screw plugs in the columns and attaching pipes. To be sure, these columns were of cast iron, but their use as air ducts represented the passage of an immense quantity of air, more or less saturated with moisture owing to being under compression.

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VERIFICATION OF THE BAZIN WEIR FORMULA BY HYDRO-CHEMICAL GAUGINGS

Discussion*

BY MESSRS. CLEMENS HERSCHEL AND DAVID A. MOLITOR.

Mr. Herschel.

CLEMENS HERSCHEL,† PAST-PRESIDENT, AM. SOC. C. E. (by letter).‡—Few engineers are in a position to appreciate from personal experience the amount of work involved in making the experiments necessary for writing a paper such as this, and in writing the paper itself. In every way such contributions should be encouraged, as they form steps in the advancement of engineering knowledge.

One criticism only the writer allows himself, and that relates merely to the title of the paper: In a strict sense, hydro-chemical gaugings are not competent to "verify" a weir formula. That can only be done by a tank, or volumetric gauging. The hydro-chemical method itself needs verification, by comparison with tank gaugings.

Still, an approximation to such a verification can be made, and is made when able engineers, like Mr. Groat, have first compared hydro-chemical results with those produced by weir gaugings made under their direction, themselves founded on comparisons with tank gaugings.

What the paper really presents is a "comparison" between the results of the Bazin and other weir formulas, and those deduced from hydro-chemical gaugings; both methods being in the same degree in need of verification.

And, if one pleases, even a tank gauging is not absolute. It is, for example, impossible to make a rod exactly 1 ft. long. Still less

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* This discussion (of the paper by Floyd A. Nagler, Jun. Am. Soc. C. E., published in January, 1918, *Proceedings*, and presented at the meeting of March 6th, 1918), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† New York City.

‡ Received by the Secretary, January 31st, 1918.

Mr. Herschel. possible to mark out exactly 1 sq. ft.; less possible again, to make a cube of which each edge shall measure exactly 1 ft.; and still less possible to gauge cubic feet per second.

The title of the paper, however, does not recognize, and is likely to mislead the reader as to, distinctions of the several sorts mentioned; of value in practice and in study, even though some of them be, if one likes, of the second degree of differentiation.

Mr. Molitor. DAVID A. MOLITOR,* M. AM. SOC. C. E. (by letter).†—This paper has been read with much interest, and, as a full account of all details and observations is given, it is possible to use the results for the verification of other formulas, aside from the one chosen by the author.

It might be expected that a purely empiric formula, like that of Bazin, based on heads up to 1 ft., would still give approximately correct results up to heads of 2 ft., and the author claims to substantiate this formula up to heads of 4 ft. However, this would, at best, hold only for absolutely identical conditions and weir dimensions.

In the Cornell experiments, made in June, 1899, by the late G. W. Rafter, M. Am. Soc. C. E., with a flume 6.53 ft. wide, and a standard sharp-crested weir, 5.26 ft. high, with a range of heads from 0.7 to 6 ft. on the crest of the weir, the agreement was not as satisfactory, showing clearly the practical limitations of an empiric formula as soon as any of the principal dimensions are changed. These experiments‡ offer an exceedingly interesting comparison with the author's results.

The Bazin formula, given by the author, contains three factors, the first of which represents the empiric coefficient generally designated by $\frac{2}{3}\mu$; the second factor is of irrational form, and the third represents the discharge through a lateral orifice. It is patterned after Weisbach's formula, proposed about 1844, as follows:

$$Q = \tfrac{2}{3}\,\mu \left[1.041 + 0.3693\left(\frac{H}{p + H}\right)^2\right] L\, H \sqrt{2\,g\,H}$$

The writer has given a general discussion§ showing the incorrectness of the several formulas quoted by the author. The King formula was not previously known to the writer, but as it is theoretically the same as the Bazin formula, with slightly altered numerical constants and the exponent of H changed from $\frac{3}{2}$ to 1.47, the same objections apply, even though the apparent agreement with the author's experimental results is better than for the other formulas as shown in Table 4.

Any formula of general applicability must express the true theoretic

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* Detroit, Mich.

† Received by the Secretary, February 14th, 1918.

‡ Given on p. 82 of the writer's "Hydraulics of Rivers, Weirs and Sluices."

§ Appendix A of "Hydraulics of Rivers, Weirs and Sluices."

Mr. Molitor.

influence of all the hydrostatic and hydrodynamic pressures and weir dimensions on the discharge. The necessity for an empiric coefficient, μ, is merely to rectify the theoretic discharge to cover the unknowable effects due to adhesion, cohesion, friction, and contraction. Such coefficients have a forced application when they are made to cover up inherent defects in a formula merely for the purpose of agreement with certain experimental data of limited scope. The mere fact that hydraulic experiments are generally confined to reasonably small cases, makes it the more necessary that the theoretic form of the formula adopted shall be rational, so as to afford some assurance of reliable results when applied to extensive weir problems such as are frequently encountered.

A keen appreciation of this circumstance prompted the writer in 1908 to publish the formulas proposed by the late Gustav Ritter von Wex.* These formulas served a most valuable purpose in solving the intricate problem of flow over the triple flight of locks at Gatun, on the Panama Canal, in order to supply the necessary hydraulic data for the design of the emergency dams with which the writer was intrusted during 1907-08.†

It may be of interest, therefore, in connection with this paper, to show the nature of the empiric coefficient, $\frac{2}{3}\mu$, as found by substituting the author's experimental data in the more rational Wex formula.

Using the author's nomenclature, Formula 22, p. 18,‡ for a uniform approach channel and vertical sharp-crested weir, becomes:

$$Q = \tfrac{2}{3}\,\mu\, L \sqrt{2\,g}\left(\frac{H}{H+\frac{p\,v^2}{g\,H}}\right)\left[\left(\frac{v^2}{2\,g}+H+\frac{p\,v^2}{g\,H}\right)^{\frac{3}{2}} - \left(\frac{v^2}{2\,g}\right)^{\frac{3}{2}}\right] \cdot\cdot (A)$$

$$\text{Where } v = \frac{Q}{L\,(p+H)}$$

$$\text{and } \tfrac{2}{3}\,\mu = 0.3818 + 0.05\,\frac{H}{p+H} + \frac{0.16}{H} + 0.00013\,L \ldots\ldots\ldots (B)$$

Taking the author's experimental values of H and Q, as given in Table 4, also $L = 6.558$ ft. and $p = 3.72$ ft., the values of $\frac{2}{3}\mu$ were computed by Equation (A) and also by Equation (B), giving the results shown in Table 5.

The values of Q are 6.558 times those given in Table 4, and represent the total discharge, instead of the "discharge per foot of weir crest." It is manifestly incorrect to compute coefficients of contraction for a flow per foot of crest for reasons clearly seen from Fig. 11, showing the distribution of velocity over the flume section and the resulting contraction adjacent to the wetted perimeter. In other words, the discharge

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* "Hydraulics of Rivers, Weirs and Sluices."

†The solution of this problem is given in Appendix B of "Hydraulics of Rivers, Weirs and Sluices."

‡ *Proceedings*, Am. Soc. C. E., January, 1918.

Mr. Molitor.

TABLE 5.

H, in feet.	Q, in cubic feet per second.	$\frac{2}{3}\mu$ Equation (A)	$\frac{2}{3}\mu$ Equation (B)	Percentage of error.
0.4	5.797	0.4272	0.4275	− 0.07
0.6	10.486	0.4175	0.4162	+ 0.31
0.8	16.034	0.4117	0.4115	+ 0.05
1.0	22.402	0.4092	0.4093	− 0.03
1.2	29.550	0.4076	0.4082	− 0.14
1.4	37.440	0.4075	0.4077	− 0.05
1.7	50.556	0.4072	0.4078	− 0.14
2.0	65.108	0.4076	0.4082	− 0.14
3.0	123.330	0.4100	0.4103	− 0.07
4.0	195 645	0.4135	0.4126	+ 0.21
	Mean =	0.4119	0.4119	....

over a weir of length, $2L$, is not equal to $2Q$, but is larger, and this difference is taken care of by the particular value of $\frac{2}{3}\mu$, and not by L. Where there is any appreciable end contraction, this effect becomes still more important.

Comparing the values of $\frac{2}{3}\mu$, as obtained from Equations (A) and (B), given in Table 5, it will be seen that the percentage of error is smaller in every case except the last one, when compared with the errors given by the King formula in Table 4, and the King formula fits the experiments more closely than any of the other formulas used for comparisons by the author. It should also be noted that the range in the values of $\frac{2}{3}\mu$ for the different heads is quite small, giving a mean value of $\frac{2}{3}\mu = 0.4119$, while the range in the values of m in Fig. 24 is from 0.436 for $H = 0.4$ ft., to 0.4255 for $H = 0.8$ or 1.0 ft., and then increases to 0.465 for $H = 4.0$ ft.

It would seem pertinent to ask why any one should deliberately make a series of experiments to prove the correctness of a formula which is admittedly wrong in theory, and does not even fit the experiments on which it was originally based.

The experimental data from all sources certainly constitute the best scientific evidence, and when the collection of facts becomes sufficiently extensive to cover the entire range of practical application, there will be no great difficulty in establishing a rational weir formula.

The difficulty surrounding this problem is a decided shortage of facts, and not formulas. Hence, the scientific answer is to increase the assortment of facts to cover most, if not all, the variables involved, thus reducing the element of speculation to a minimum.

In overlooking the Rafter experiments, the author evidently failed to avail himself of the best information so far given to the Profession. It might be interesting, therefore, to mention that Mr. Rafter conducted his experiments at the request of the United States Deep Water-

Mr. Molitor.

ways Commission, because the experiments and formulas given by Bazin were not deemed sufficiently wide in scope to justify their adoption in the solution of the many important questions which this Commission was required to answer. The results obtained by Mr. Rafter fully justified the views of the Commission.

A careful inspection of Fig. 24 shows quite conclusively that all experiments made on heads up to 1 ft. would lead to very erroneous conclusions when applied to heads much larger than this, and hence the high-head flows are those which must be investigated, if any valuable contribution to our knowledge on this subject is expected. As the hydro-chemical method of gauging is likely to fail on account of excessive cost and other technical difficulties regarding imperfect mixtures, etc., we must ultimately look to current-meter measurements for a final answer to large weir problems.

There can be no doubt of the high relative accuracy attainable by hydro-chemical gaugings, but whether the same degree in absolute accuracy can be secured is still to be proved.

After a careful comparison of the author's results with those of Bazin and Rafter, it appears that the discharges within the scope of actual measurements are in every case smaller than those observed by the author. This seems to indicate the presence of constant or periodic errors affecting either the author's experiments, or else all the other measurements combined.

Although the weighing method is no doubt inaccurate within certain limits, the errors are more likely to be of a compensating nature, and repeated measurements would tend to reduce their magnitude.

The chemical method would probably involve smaller accidental errors, but might be afflicted with more or less serious constant errors, which would not be revealed until the results are compared with those obtained from an entirely different process of gauging, such as that used by Bazin and Rafter.

For instance, the determination of chlorine by the silver nitrate titration, with chromate indicator, is permissible only in neutral solutions and in the absence of organic matter. The presence of alkalis, acids, or organic substances in the natural pond water, unless carefully allowed for, would lead to constant errors in the results. It is also possible that some of the salt solution introduced at the dosing station never reaches the sampling station and is lost by absorption in the flume walls, etc. Furthermore, the range in velocity variation on any cross-section, as shown by Fig. 11, where the head = 2.97 ft., is from 3.3 ft. per sec. down to 1 ft. next to the wetted perimeter, and may be even less than this, would affect the time of travel between the dosing and sampling stations (108.7 ft.) by from 33 to 108 sec. or more. As a matter of fact, some of the salt introduced during an experiment might not reach the weir or sampling station until long after the

Mr. Molitor. experiment was over. Then again, the location of the holes in the sampling pipes might not give the peripheral flow sufficient weight in the samples taken, and frictional losses in the sampling pipes might account for some retardation in relative strength of samples. All these influences might easily account for some periodic errors, which would not necessarily be of the same sign over the entire range of the experiments (as there may be different constant errors of opposite signs) and thus account for the fundamental differences or apparently large errors disclosed between the author's gaugings and those of Bazin and Rafter.

All this would lead to the inference that it was a mistake to assume the hydro-chemical gaugings to represent the best attainable results simply because they apparently fit the Bazin formula, even though Bazin's own experiments do not agree so fully with his formula. As experiments are always more important than the formulas based thereon, the author might better seek for an explanation of the inherent differences between his own and other experimental data, and in the event that he succeeds in this, he will no doubt merit full credit for his ardent labors.

This discussion is offered with the sincere desire to assist the author in achieving such results as may be of the greatest possible value, both to himself and the Profession.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

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DISCUSSION ON FINAL REPORT OF THE SPECIAL COMMITTEE ON STEEL COLUMNS AND STRUTS*

By J. A. L. Waddell, M. Am. Soc. C. E.

Mr. Waddell.

J. A. L. Waddell,† M. Am. Soc. C. E. (by letter).‡—The drastic step taken by the Committee in establishing the intensity of working compressive stress in carbon-steel struts at 12 000 lb. for all values of $\frac{l}{r}$ below 80, and beyond that range reducing it according to the formula,

$$C = 12\,000 - 100\left(\frac{l}{r} - 80\right),$$

up to the limit of $\frac{l}{r} = 120$, does not appear to the writer to be warranted by certain facts.

In the first place, the sections used for testing are small, as compared with those used in bridgework for chord members; although they are more nearly normal for web members. Besides, most of the types of struts tested had open faces, though bridge chords generally have one cover-plate and one laced face. Again, there should have been a series of tests for comparatively small values of $\frac{l}{r}$, because it is hardly conceivable that a short block will not resist compression at least as well as any member made of the same metal will resist

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* Continued from February, 1918, *Proceedings*.

† New York City.

‡ Received by the Secretary, February 25th, 1918.

Mr. Waddell. tension. In the years long gone by, it was the prevalent opinion that such short struts could be stressed somewhat higher per square inch than the tension members; then custom decreed that the limiting intensities of working stresses should be alike; but now comes a further and most radical cut, amounting to 25 per cent. The Engineering Profession should pause a little before incorporating this innovation into its standard bridge specifications.

Some 14 years ago the writer made twelve tests of struts of both carbon steel and nickel steel, the sectional area thereof being 17.5 sq. in., and the lengths 10 and 30 ft., making the values of $\frac{l}{r} = 27$ and 81, respectively. The results of these tests were published by the Society in 1909 in a paper entitled "Nickel Steel for Bridges",* from which paper it can be seen that the carbon-steel struts gave, as averages, unit elastic limits of 28 800 lb. for the short ones and 16 800 lb. for the long ones, the corresponding unit ultimate strengths being 39 200 and and 30 500 lb. It is true that all the struts had hinged ends, hence, to compare the results with those found by the Committee, they should be increased about in the ratio of

$$R = \frac{16\,000 - 60\,\frac{l}{r}}{16\,000 - 80\,\frac{l}{r}}.$$

Substituting $\frac{l}{r} = 27$ and $\frac{l}{r} = 81$, we have, respectively, 1.04 and 1.17.

Applying these figures, we find, for the elastic limits, 29 950 and 19 660, and, for the ultimate strengths, 40 770 and 35 690.

It is difficult to compare these figures with the averages of those found by the Committee, because it did not determine the elastic limit, but, instead, a new function designated "Useful Limit Point". It is true that the writer's method of determining the elastic limit was arbitrary; but it was conservative. For the value of $\frac{l}{r} = 85$ (which, for comparison, is sufficiently close to the writer's superior limit of 81) the Committee found, as averages, for the "Useful Limit Point" and the ultimate strength, respectively, 27 100 and 30 200. The former possibly might properly be compared with the average of the results obtained by the writer, in the case of the longer columns, for a permanent set of 0.015 in., *viz.*, 21 300, which, of course, as before, must be multiplied by 1.17, making 24 920.

Comparing the ultimate strengths, we have 30 200 lb. per sq. in. found by the Committee, against 35 690 lb. found by the writer. As the quality of the metal was practically the same in both cases, this

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* *Transactions,* Am. Soc. C. E., Vol. LXIII, p. 101.

Mr. Waddell

great difference is presumably due primarily to the fact that the writer's struts were detailed so perfectly that they developed the greatest possible strength from the section, which apparently was not the case in some of the Committee's test struts.

The writer's latest specifications for designing* permit the following intensities of working stresses for carbon-steel columns:

For fixed ends,

$$C = 16\,000 - 60\,\frac{l}{r},$$

and for hinged ends,

$$C = 16\,000 - 80\,\frac{l}{r}.$$

Substituting in the latter 27 and 81 for $\frac{l}{r}$, we have, respectively, 13 840 and 9 520. Comparing these figures with the results of the writer's tests, which gave for the elastic limits 28 800 and 16 800, we find the ratios to be 0.48 and 0.57. As the aim in preparing the formulas was to make the intensity of working stress about one-half of the elastic limit, it is evident that there is an error of 2% on the side of safety for the short columns, and one of 7% on the side of danger for the long columns. It must be remembered, though, that for the latter the writer used a very conservative method in trying to locate the elastic limit.

These experiments by the writer show conclusively the fallacy of using a constant intensity of working stress up to a limit of $\frac{l}{r} = 80$; because (when corrected for fixedness of ends) the elastic limits are 29 950 for $\frac{l}{r} = 27$ and 19 660 for $\frac{l}{r} = 81$. Taking one-half of each of these, we have, for the allowable working intensities, approximately 15 000 and 10 000 lb., though the Committee would use 12 000 lb. for both cases. This shows that the Committee's assumption is illogical. The writer's formula for fixed ends makes these intensities 14 380 and 11 140. Therefore, it does not seem justifiable to stress as high as 12 000 lb. for $\frac{l}{r} = 80$; and it is decidedly uneconomic to use that intensity for $\frac{l}{r} = 20$ or 30, as would be the case in chord sections of many railroad bridges.

In the writer's 42 years' experience, connected mainly with bridges, he cannot recall a single instance of the failure of a properly designed compression member, but he has known of tension members failing,

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* "Bridge Engineering", Chapter LXXVIII.

Mr. Waddell.

although, truth to tell, not many of them, except in detail. Were it true that we were over-stressing short columns some 35% when using for fixed ends the old standard formula,

$$C = 18\,000 - 70\,\frac{l}{r}.$$

there inevitably would have been numerous column failures in old bridges in which the actual intensities of working stress on the tension members approached the danger limit.

As for the great differences in resistance between struts fabricated with thin metal and those fabricated with thick metal, the adoption of more thorough and cooler rolling for the latter would probably reduce that difference materially. In any case, though, we should certainly need more experiments on this point before upsetting fundamentally the standard practice of American bridge engineers.

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PAPERS AND DISCUSSIONS

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STRESS MEASUREMENTS ON THE HELL GATE ARCH BRIDGE

Discussion*

By Messrs. John I. Parcel and H. M. MacKay.

John I. Parcel,† Esq. (by letter).‡—The writer has read this very able paper with great interest. The introduction of the strain gauge marks a definite epoch in the development of the science of structural design, and the remarkable large-scale experiment which this paper reports can hardly fail to encourage a much more extensive application of this instrument to the practical problems of the structural engineer. Mr. Parcel.

Certain of the author's conclusions on secondary stresses seem to the writer to be open to argument, and he would like to raise a few questions regarding them. As bearing on secondary stresses in general, perhaps the two most important conclusions stated in the paper are:

1.—Actual secondary stresses, in general, will be less than the computed stresses, due largely to a constant automatic re-adjustment of the internal strains tending toward the relief of secondary stresses.

2.—For most bridges it will probably be satisfactory to provide for secondary stresses by an allowance in the specified unit stresses of about 20% of the total primary stress, plus 3 000 lb.

Perhaps the first conclusion is entirely sound, but some question may be raised as to its deduction from the data of this experiment. Fig. 5, as the author explains on page 1831,§ shows the curve of

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* Discussion of the paper by D. B. Steinman, Assoc. M. Am. Soc. C. E., continued from February, 1918, *Proceedings*.

† Associate Professor, Structural Eng., Univ. of Minnesota, Minneapolis, Minn.

‡ Received by the Secretary, February 5th, 1918.

§ *Proceedings*, Am. Soc. C. E., October, 1917.

Mr. Parcel. measured secondary stress approaching the calculated curve continuously from Stage 1 to Stage 6, as the joint condition approaches more nearly the rigidity assumed in the computation of secondary stresses, diverging again as a release of direct compression permits partial hinge action at the joints, and finally crossing above the calculated curve after Stage 12, when the compression is so great that the joints are completely fixed. At the final stage, *2-H*, when the primary stress reaches its maximum, the average measured secondary stress is more than twice the computed value. The action of the three-faced butt joints, in concentrating the direct stress near the middle of the section so as practically to nullify the bending effect, shows a remarkably happy solution of the problem in the chords of the Hell Gate Arch, but it remains true that the measured bending stresses are more than double their calculated value. A. H. Fuller, M. Am. Soc. C. E., has pointed out that, for nearly all cases where the primary stress is greater than 3 000 lb. per sq. in., the measured secondary stresses are greater than the corresponding computed stresses. Plate XXXVI shows eighteen measurements for secondary stresses where the measured primary is 3 000 lb. or more, and in all but two cases the measured value is equal to or greater than the calculated value. For the final stage, *2-H*, the average of the computed secondaries is 6% and the average of the corresponding measured values 13 per cent. That these two figures are fairly comparable is indicated by the author's formula (page 1828) where he takes 12% as an average value for secondary stress proper—*i. e.*, that induced by rigidity of joints when the truss distorts in its own plane. The writer cannot help feeling, with Professor Fuller, that this point is of more significance than the author seems to attach to it, and he would like to inquire if there are reasons, other than appear on the surface, for minimizing its importance. If not, the following additional conclusion might fairly be drawn; "for the higher ranges of primary stress, the actual secondary stresses will probably exceed the calculated values by a considerable margin." As in all ordinary cases it is only the secondary stresses that co-exist with the maximum primary stresses that affect the design of the structure, this result would seem more significant practically than the fact that the higher percentages of calculated secondary stress are not borne out by the test.

The second conclusion noted above, regarding an allowance in the specified unit stresses of 20% plus 3 000 to cover secondaries, is of interest in its attempt to distinguish between the two kinds of secondary stress: that which is proportional to the primary, and that which is independent of it, a method which seems quite logical and clearly justified by the data of the test. But it may well be asked here whether any empirical relation based on averages is an adequate means of providing for secondary stresses, even in ordinary structures. Perhaps

Mr. Parcel.

the author does not mean the formula to be used as a substitute for calculations, but he says, on pages 1828 and 1829:

"It is recognized, of course, that a rule of this form can properly apply only to structures in which the secondary stresses have normal or average values. Where unusually large secondaries may be anticipated, these should be given special investigation and attention."

This would seem to imply clearly that only the unusual cases need such investigation. To the best of the writer's knowledge, some form of average allowance applied to all members is the common method of providing for secondary stresses in most structural offices, except for very large structures or those of unusual types. None the less, such a practice appears to the writer to involve a serious inconsistency.

Let it be assumed, first, that the theoretical calculation of secondaries gives results even roughly reliable. Now, it is well known that standard types of simple trusses of moderate span will show effective secondary stresses (those occurring simultaneously or nearly so with maximum primaries) ranging from 5% in some members to 50% or more in others. Take, for example, the 396-ft., pin-connected, Petit truss.* This is fairly typical of the commonest type of trusses for spans ranging from 300 to 600 ft. In four of the seven top-chord members the effective secondary is about 15%; in the others it is more than 60 per cent. To say that the average is 35%, and thus design the structure, would seem quite indefensible, in view of the standard of accuracy maintained in the calculation of primary stresses.

If we assume that theoretical computations for secondaries are wholly untrustworthy, and thus justify reliance on an empirical formula for ordinary bridges, how are we to rely on our analysis for the cases where "exceptionally large secondaries may be anticipated", and what basis is there for the elaborate and very expensive correction methods used in the erection of the Quebec and Sciotoville spans, methods which have been referred to in current technical literature as the most remarkable single feature of these great engineering projects?

We need a great many more experimental data to settle the question of actual *versus* calculated secondary stresses, no doubt; but the bulk of the evidence, up to the present, would seem to justify considerable confidence in our theory. Most previous tests, as shown by the author's citations, show fair agreement between the calculated and observed stresses. In how far the large discrepancies in the test under discussion are due to the unique conditions of the structure is uncertain. The author evidently feels that a considerable part of the discrepancy is due to a relief of the secondaries by re-adjustment of internal strain, and the writer does not care to dispute this point; but the relatively

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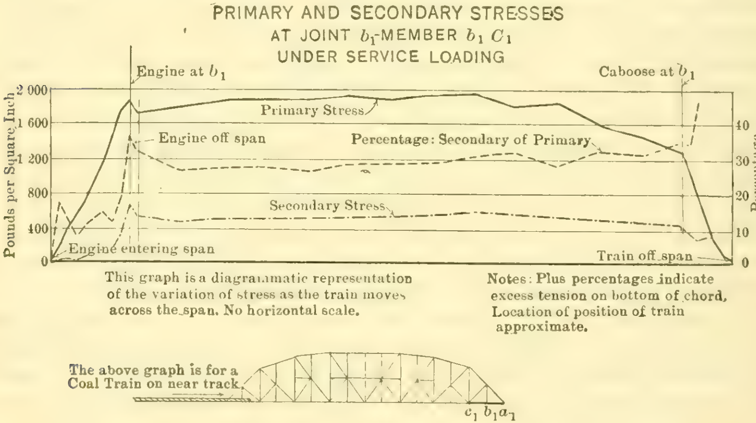
* As analyzed in the *Bulletin* of the American Railway Engineering Association, January, 1914, p. 454.

Mr. Parcel. close correspondence between the measured and calculated curves at Stages 5 and 6, and at 3-*H* and 2-*H*, where the actual condition of the joints approaches that assumed in the calculations, seems most significant, and until we have more definite experimental evidence that our theoretical calculations are untrustworthy is it not worth while, even in structures of ordinary span, to provide, at least, for secondary stresses on the basis of some approximate analysis?

It is stated on page 1829 that a comparison of individual values of calculated and measured secondary stresses is not very illuminating because of the many disturbing factors which would tend to obscure the systematic variations. The writer has had some part in a recent test to determine some of the secondary stresses in the 518-ft. riveted span of the Norfolk and Western Bridge over the Ohio River at Kenova, W. Va. This test, made possible by the generous co-operation of J. E. Crawford, M. Am. Soc. C. E., Chief Engineer of the Norfolk and Western Railway, was in no wise comparable in magnitude to the Hell Gate Arch test, the principal object being to compare the computed with the measured secondary strains under service loading at a few typical joints. The data of the test are not yet completely analyzed, and any general conclusions deduced would be premature. The graphs of Figs. 9, 10, and 11 are fairly typical, as direct reductions of field data, and the writer has thought they may be of some interest to members of the Society as they stand.


PRIMARY AND SECONDARY STRESSES AT JOINT b_1-MEMBER b_1C_1 UNDER SERVICE LOADING

This graph is a diagrammatic representation of the variation of stress as the train moves across the span. No horizontal scale.

Notes: Plus percentages indicate excess tension on bottom of chord. Location of position of train approximate.

The above graph is for a Coal Train on near track.

FIG. 9.

Before making a quantitative comparison with calculated values, the data must be corrected for the location of the instruments, as it was never practically possible to take readings at the extreme edge of the cross-section or the extreme ends of the members. These corrections will generally result in greatly increasing the secondary stress

Mr. Parcel. percentages. Before the test was made, the truss was analyzed by joint loads, and influence lines were constructed. These showed that the bending at the lower chord point, b_1, maintained the same direction for all loads, and that the maximum secondary occurred at full loading, though the upper chord points, G and F_1, at bending, reverse during the passing of a single load, and the maximum secondaries occur under partial loading. This effect is very clearly brought out, qualitatively, in the curve shown. Several complete sets of readings were taken on each joint tested, and the results were so consistent that, when the data are fully analyzed, it is hoped that a joint-by-joint comparison can be made between measured and computed secondaries, which will be of some interest and value to the Profession.

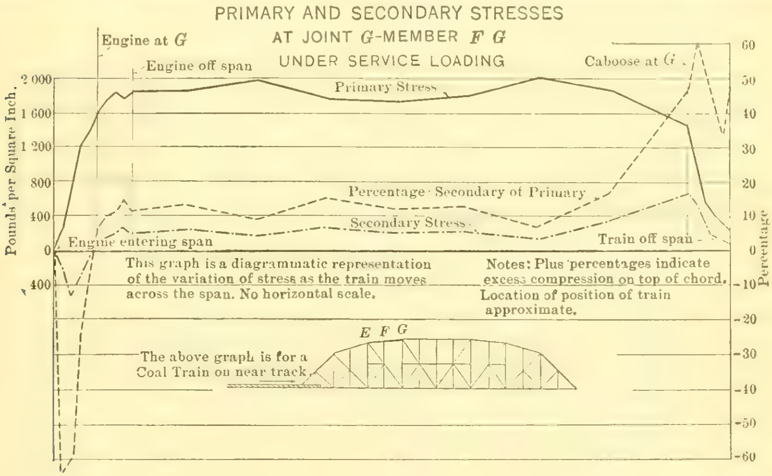


FIG. 10.

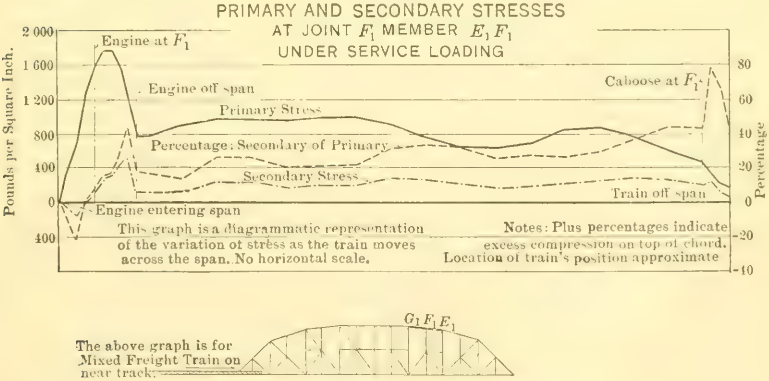


FIG. 11.

Mr. MacKay. H. M. MacKay,* M. Am. Soc. C. E. (by letter).†—The possibilities of the Howard gauge and other extensometers, as a means of investigating the distribution of stress in structures, do not seem to be as widely appreciated as they should be. The writer, therefore, welcomes this valuable paper, not only for the information it contains, but because it is likely to attract attention to a method of investigation which deserves to be used far more frequently.

The author states:

> "To secure full information as to the distribution of stress in any member, it is necessary to take measurements at not less than three, and preferably four, points of the cross-section near each end of the member."

The writer believes that a considerably greater number of points are usually desirable in large members; and he considers the statement: "The intensity of stress at any other point of the member can then be found by planar and linear interpolation," likely to prove very misleading. If literally accepted, the result would often be to cast doubt on this method of investigation. In the case of box members, to be sure, and other members with rigid transverse webs, such interpolation might often give fairly good results. Nevertheless, from the figures in Tables 4 and 6, several instances may be noted where the omission of the observations near the centers of the webs would have altered the results quite appreciably. Thus in Member 4-6, Stage 10, the mean of six observations gives, at the lower end, a stress of — 2 675 lb. per sq. in. The four corner measurements, taken by themselves, would give — 3 037, a difference of nearly 14 per cent. Again, considering Member 4-6, Stage 2H, the omission of the two readings at the center of the web would have given average stresses of — 9 710 and — 10 980, at the lower and upper ends, respectively, as compared with — 10 250 and — 13 050, obtained from the mean of six readings.

In the case of latticed members and others in which the component parts are less rigidly connected than are those of the lower chord of the Hell Gate Arch, the importance of making a considerable number of observations at each section is greater. Fig. 12 shows the stress distribution, at two stages of loading, in a latticed member tested by the writer, and consisting of four 4 by 4 by $\frac{3}{8}$-in. angles and two 22 by $\frac{3}{8}$-in. webs. The load was applied through 7-in. pins, and the section represented was near the inner end of the pin-plates. The stresses are plotted on an elevation of the member from a base line at the left of the figure, so as to show the distribution at a glance. Taking E as 29 000 000 lb. per sq. in., we have:

Average measured stress....	— 6 025	— 14 430
Actual stress..............	— 6 380	— 14 720

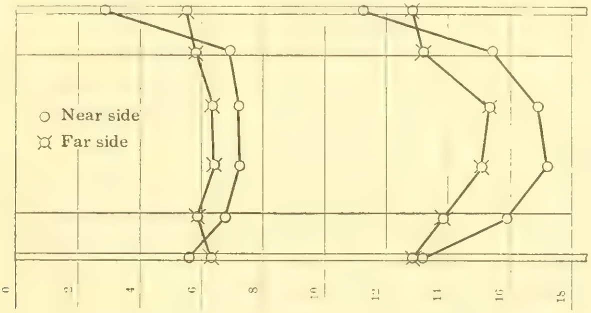
---

* Montreal, Que., Canada.

† Received by the Secretary, February 18th, 1918.

Mr. MacKay.

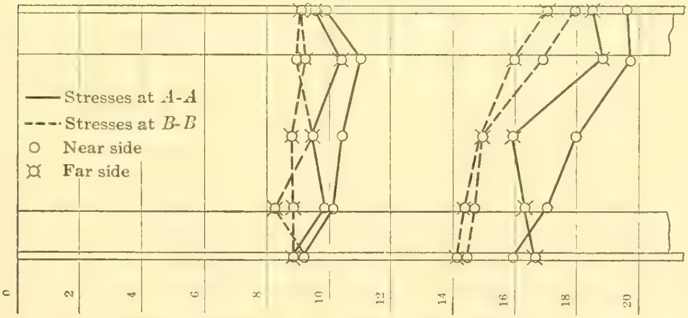
Although the pin-plates were of ample length and well designed, the concentration of stress near the center of the web is clearly marked. Many such instances might be given, the condition being quite characteristic of the stress distribution near the ends of pin-connected members. It is clear that in such cases planar interpolation from three or four points would give very misleading results.



Stresses, in Thousands of Pounds per Square Inch.

DISTRIBUTION OF STRESS NEAR PIN-PLATES AT TWO STAGES OF LOADING.

FIG. 12.



Stresses, in Thousands of Pounds per Square Inch.

COMPARATIVE STRESSES AT DIAPHRAGM AND AT ADJACENT SECTION.

FIG. 13.

Fig. 13 shows the stress distribution in a similar, but somewhat heavier, member. The full lines indicate the stresses over a 10-in. gauge length, at the center of which a transverse diaphragm is inserted; the dotted lines show the stresses over the same gauge length, the center of which is 10 in. from the diaphragm. Fig. 14 indicates the relative positions of the lattice bars, diaphragm, and points of measurement. Under compression, the tendency of the lattice bars is to push

Mr. MacKay.

the ribs apart, and the restraining action of the diaphragm sets up bending stresses in the ribs, which are clearly indicated, as follows:

Applied load	9 240 lb. per sq. in.
Average measured stress at diaphragm	9 920 " " " "
" " " 10 in. away	9 120 " " " "
Applied load	15 530 " " " "
Average measured stress at diaphragm	17 630 " " " "
" " " 10 in. away	15 770 " " " "

All measurements were taken on the outside of the ribs. Although the diaphragm was designed so as to be fairly flexible, it increases the stress in the rib nearly 12 per cent. A shorter gauge length would possibly indicate higher bending stress, and a stiffer diaphragm would undoubtedly increase the effect. Linear interpolation between observations taken at the ends of a member would miss such tertiary effects altogether; and those interested in stress measurements cannot be too often reminded that a thorough study of the action of built-up members demands a complete survey of the whole member.

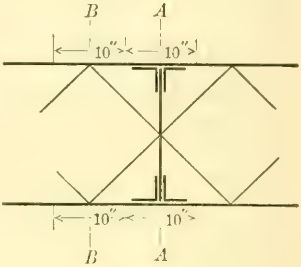


FIG. 14.

The writer cannot share the apprehensions of those who consider the Howard gauge too defective in principle to give good results. It is not easy to protect external holes for a long period on outside work. Any accidental blow in the vicinity of a point of observation may vitiate the results for comparative purposes; also, the writer does not know of any entirely satisfactory material for plugging the holes. Other proposed methods, however, would present similar difficulties. If the gauge is tilted, the contact is between an ellipse and a circle, and, provided that the points are conical, the maximum error is the difference between the semi-major and the semi-minor axes of the ellipse. With a 55° point and a hole 0.03 in. in diameter, a tilt of 5°, which is extravagant, would allow a maximum error of about 0.0001 in.

MEMOIRS OF DECEASED MEMBERS

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

OTIS FRANCIS CLAPP, M. Am. Soc. C. E.*

DIED MARCH 3D, 1917.

Otis Francis Clapp was born in Boston, Mass., on September 26th, 1843, and was educated in the public schools and Hunt's Academy at North Bridgewater, now Brockton, Mass.

He began his engineering training in the office of Messrs. Shedd and Edson, in Boston. In 1867 he was sent by that firm to Providence, R. I., to make the preliminary surveys for the first municipal water-works system. The project, which was afterward adopted, provided for a water supply from the Pawtucket River.

In 1872, Mr. Clapp was given charge of the preparation of the plans for a sewerage system for the City of Providence, and, later, the greater part of the city's sewers and sewage disposal works was constructed under his direction.

In May, 1897, he was appointed City Engineer to succeed the late J. Herbert Shedd, M. Am. Soc. C. E. Mr. Clapp held this office for 18 years, until 1916, when he was made First Assistant in the City Engineer's Department on special work in connection with the improvement of the Moshassuck River channel. He was engaged on this work for nearly a year, but was obliged to resign on account of his failing health. Altogether, Mr. Clapp had been connected with the engineering work of the City of Providence, particularly that part of it relating to the water-works and sewerage departments, for more than 50 years.

He was a man of pleasing personality, modest and unassuming in manner, and of a genial temperament which attracted to him many friends.

In November, 1869, he was married to Anna Isabella Sweetland, whom he survived about two years.

Mr. Clapp was a member of the Boston Society of Civil Engineers. He was elected a Member of the American Society of Civil Engineers on March 2d, 1898, and at the time of his death was serving as a member of the Board of Direction, to which office he had been elected on January 19th, 1916.

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* Memoir prepared by the Secretary from information furnished by William D. Bullock, M. Am. Soc. C. E.

PAPERS IN THIS NUMBER

"THE ECONOMICS OF STEEL ARCH BRIDGES." J. A. L. WADDELL. (To be presented May 1st, 1918.)

PAPERS AND DISCUSSIONS CURRENT IN PROCEEDINGS

Final Report of the Special Committee on Concrete and Reinforced Concrete.... Dec., 1916
Discussion...Feb., Mar., Apr., May, Aug., Sept., Oct., 1917, Jan., Feb., 1918

"Cement Joints for Cast-Iron Water Mains." CLARK H. SHAW.... Mar., 1917
Discussion.... May, Aug., "

"Modern Practice in Wood Stave Pipe Design and Suggestions for Standard Specifications." J. F. PARTRIDGE.... Apr., "
Discussion.... Aug., Sept., Oct., "

"Obstruction of Bridge Piers to the Flow of Water." FLOYD A. NAGLER...May, "
Discussion.... Sept., Nov., 1917, Jan., Feb., 1918

"The Three 15-Cubic Yard Dipper-Dredges, *Gamboa*, *Paraiso*, and *Cascadas*, as Supplied and Used on the Panama Canal." RAY W. BERDEAU.... Aug., 1917
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Discussion.... Nov., "

"Detention Reservoirs with Spillway Outlets as an Agency in Flood Control." H. M. CHITTENDEN.... Sept., "
Discussion.... Nov., Dec., 1917, Jan., Feb., 1918

"A Phenomenal Land Slide—Supplement." D. D. CLARKE.... Sept., 1917
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Discussion.... Dec., 1917, Jan., Feb., Mar., 1918

"Construction Problems of the Manhattan-Bronx, and Lexington Avenue Subway Junction and Queensborough Tunnel Connections." GEORGE PERRINE.... Nov., 1917
Discussion.... Jan., Feb., 1918

"The Activities of the American Society of Civil Engineers During the Past Twenty-five Years." CHAS. WARREN HUNT.... Dec., 1917
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"Ice Diversion, Hydraulic Models, and Hydraulic Similarity." BENJAMIN F. GROAT.... Dec., 1917
Discussion.... Feb., Mar., 1918

"Manhattan Elevated Railway Improvements." F. W. GARDINER and S. JOHANNESSON.... Dec., 1917
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Final Report of the Special Committee on Steel Columns and Struts.... Dec., 1917
Discussion.... Feb., Mar., 1918

Progress Report of the Special Committee on the Regulation of Water Rights. Dec., 1917
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PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XLIV—No. 4

AMERICAN
SOCIETY OF
CIVIL
ENGINEERS
FOUNDED
1852

April, 1918

Published at the Headquarters of the Society, 33 West Thirty-ninth Street, New York, the Fourth Wednesday of each Month, except June and July.

Copyrighted 1918, by the American Society of Civil Engineers.
Entered as Second-Class Matter at the New York City Post Office, December 15th, 1896.
Subscription, $8 per annum.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852)

VOL. XLIV—No. 4

APRIL, 1918

Edited by the Secretary, under the direction of the Committee on Publications.

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ON THE REGULATION OF WATER RIGHTS: F. H. Newell, W. C. Hoad, John H. Lewis.

TO REPORT ON STRESSES IN RAILROAD TRACK: A. N. Talbot, A. S. Baldwin, G. H. Bremner, John Brunner, W. J. Burton, Charles S. Churchill, W. C. Cushing, Robert W. Hunt, George W. Kittredge, Paul M. LaBach, C. G. E. Larsson, G. J. Ray, Albert F. Reichmann, H. R. Safford, F. E. Turneaure, J. E. Willoughby.

◆

The Reading Room of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

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Vol. XLIV. APRIL, 1918. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

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SOCIETY AFFAIRS

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MINUTES OF MEETINGS

OF THE SOCIETY

March 20th, 1918.—The meeting was called to order at 8.30 P. M.; Vice-President Nelson P. Lewis in the chair; Chas. Warren Hunt, Secretary; and present, also, 67 members and 7 guests.

A paper by W. C. Hammatt, M. Am. Soc. C. E., entitled "Determination of the Duty of Water by Analytical Experiment" was presented by the Secretary. The subject was discussed by Messrs. J. C. Van Reigersberg Versluys and T. Kennard Thomson.

C. F. Brown, M. Am. Soc. C. E., gave a description of his experience in the handling of unusual drainage problems, illustrating his remarks with lantern slides.

The Secretary announced the election of the following candidates on March 12th, 1918:

As Members

George Francis Burch, Springfield, Ill.
John Henry Butters, Hobart, Tasmania, Australia
Maurice Griest, New York City
Everson Clifton Hulbert, Wampum, Pa.
Gilbert Edwin Humphrey, Norfolk, Va.
James Albro Lawrie, Duluth Minn.
Alexander MacGlashan, Camp McClellan, Anniston, Ala.
Maynard Sargent McDanel, Richmond, Va.
Vladimir Adolfovitch Nagrodsky, Petrograd, Russia
Joseph Herbert Redding, Camden, N. J.
Arthur Arnold Tenney, Fitchburg, Mass.
William Lawrence Waters, New York City
Irving Weed, Brooklyn, N. Y.

As Associate Members

George Norris Adams, Los Angeles, Cal.
Leonidas Metcalf Allison, Philadelphia, Pa.
William Manning Bassett, Yonkers, N. Y.
Carl Eugene Beam, North Yakima, Wash.
Linus Cramblet Blackwell, Bellevue, Pa.
Walter Braun, Columbus, Ohio
Lloyd C. Britton, Jasper, Ala.
Ansel Morris Burton, Kansas City, Mo.
George Valentine Clow, Dayton, Ohio
Edward Cowen Connor, Dallas, Tex.
Aaron Sanford Craven, Philadelphia, Pa.
Clyde Raymond Dodge, Bronxville, N. Y.
Alfred William Alexander Eden, East Orange, N. J.
Ward Herbert Fisher, Mt. Comfort, Ind.
Edmund Joseph Fitzmaurice, Philadelphia, Pa.
Arthur Oscar Forster, Philadelphia, Pa.
Albert Francis Geiger, Bridgeport, Conn.
Carl Joseph Gooch, Taunton, Mass.
Emil Niles Gustafson, Bay City, Tex.
Bert Marcellus Hart, Oklahoma City, Okla.
Cecil Blaine Hopkins, San Francisco, Cal.
William James Horrigan, Beaufort, N. C.
Harvey Willard Jones, Minneapolis, Minn.
Hugh Latimer, New York City
John Frank Lidral, Seattle, Wash.

LEWIS WEDSEL MCINTYRE, Pittsburgh, Pa.
WYNN MEREDITH, Fortuna, Cal.
HARRY WORTHINGTON MIXSELL, Phillipsburg, N. J.
CHARLES AUDIE MOORE, Chicago, Ill.
FENWICK HALL MURRAY, Columbia, S. C.
PENNELL CHURCHMAN PAINTER, Baltimore, Md.
SAMUEL REYNOLDS PARKE, Camp Hill, Pa.
JAMES HENRY POLHEMUS, Marshfield, Ore.
HOMER PUCKETT, Chattanooga, Tenn.
PHILIP RAPP, Buffalo, N. Y.
EDWIN GEORGE REYNOLDS, JR., New Rochelle, N. Y.
JOHN PHILIP RICKARD, Rochester, N. Y.
ARTHUR HERBERT RINEY, Camp Meade, Md.
JAMES WALLACE ROWLAND, Philadelphia, Pa.
LLOYD SCHWARTZ, Aurora, Ill.
GEORGE HUDSON SEYBOLT, West New Brighton, N. Y.
AUSTIN FERREE SHURE, Baltimore, Md.
FREDERICK PHILIP STABELL, New Haven, Conn.
HOWARD LOGAN STILLWELL, Atlanta, Ga.
HAAKON HOLDT SVANÖE, Milwaukee, Wis.
CARROLL ROSE THOMPSON, Philadelphia, Pa.
ROBERT HARRY TOMPKINS, Camp Bowie, Fort Worth, Tex.
LEONARD CHURCH URQUHART, Ithaca, N. Y.
JAMES PARRISH WELLS, Le Roy, N. Y.
PERRY ALLEN WELTY, San Benito, Tex.
JOHN KENNEDY WILLIAMSON, Bridgeport, Conn.

AS JUNIORS

WALTER FRANCIS ADAMS, Camp Meade, Md.
EARLE ANDREWS BURT, Altadena, Cal.
JOHN TOWNSHEND CHILD, Rochester, N. Y.
HERBERT NELSON EATON, Worcester, Mass.
ALEXANDER HOLLIS GODFREY, Cynwyd, Pa.
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FREDERICK FRANK STAGER, Carnegie, Pa.
STACEY HARRISON WIDDICOMBE, Phœnixville, Pa.
EDWARD AUGUSTUS WIGHT, Balboa Heights, Canal Zone, Panama
EDWARD LOUIS ZELTNER, New York City

The Secretary announced the transfer of the following candidates on March 12th, 1918:

From Associate Member to Member

Frank La Fayette Anders, Fargo, N. Dak.
Asher Atkinson, New Brunswick, N. J.
Ralph Agustus Beebe, San Francisco, Cal.
John Vanderveer Beekman, Jr., Boston, Mass.
Alger Adams Conger, Worcester, Mass.
James Lyford Davis, Manchester Center, Vt.
James Laird de Vou, Pittsburgh, Pa.
Frederick Herston Frankland, Kansas City, Mo.
Lee Morgan Jones, Port Arthur, Ont., Canada
Lawrence Milton Lawson, El Paso, Tex.
William Otto Lichtner, Boston, Mass.
Julio Daniel Montero, Havana, Cuba
Henry Garfield Perring, Baltimore, Md.
Ralph Edgar Spaulding, Suffield, Conn.
Warren Chamberlain Tudbury, Washington, D. C.
Walter Austin Wheeler, Kansas City, Mo.
Allan Sheldon Woodle, Jr., Eddystone, Pa.

From Junior to Associate Member

Charles Cecil Campbell, Philadelphia, Pa.
William Mack Eliot, Houston, Tex.
Lyman Russell Flook, Ann Arbor, Mich.
Whitney Irwin Gregory, Louisville, Ky.
John Zadok Street, New Castle, Pa.
Lloyd Woolsey Weed, Boston, Mass.
Chauncy Wernecke, Seattle, Wash.

The Secretary announced the following deaths:

Charles Otto Brown, of Brooklyn, N. Y., elected Junior, January 6th, 1875; Member, November 7th, 1877; died March 10th, 1918.

Oliver Zell Howard, of New York City, elected Associate Member, February 28th, 1911; Member, May 15th, 1917; died December 20th, 1917.

Edwin Augustus Stevens, of Hoboken, N. J., elected Member, June 3d, 1915; died March 8th, 1918.

John D. Van Buren, of New Brighton, N. Y., elected Member, May 20th, 1868; died March 11th, 1918.

Plumer Henry Smith, of Houston, Tex., elected Associate Member, January 7th, 1913; died January 18th, 1918.

Adjourned.

April 3d, 1918.—The meeting was called to order at 8.30 P. M.; Vice-President George W. Kittredge in the chair; Chas. Warren Hunt, Secretary; and present, also 174 members and 14 guests.

The minutes of the meetings of February 20th and March 6th, 1918, were approved as printed in *Proceedings* for March, 1918.

George W. Fuller, M. Am. Soc. C. E., gave an informal talk on "Emergency Construction Work Due to War Conditions", illustrating his remarks with lantern slides.

On motion, duly seconded, the thanks of the meeting were tendered to Mr. Fuller for his very interesting address; and he was requested to prepare the material presented for publication in *Proceedings*.

The Secretary announced that the Executive Committee of the Board of Direction had decided that, as a matter of economy, the usual collation served after the meetings would be discontinued during the period of the war.

The Secretary announced the following deaths:

EMORY WASHBURN MUENSCHER, of Manistee, Mich., elected Member July 5th, 1893; date of death unknown.

STACY BROWN OPDYKE, JR., of Philadelphia, Pa., elected Member February 2d, 1876; died October 24th, 1917.

FRED ELMER WILCOX, of Pasadena, Cal., elected Associate Member April 1st, 1896; died March 21st, 1918.

Adjourned.

SOCIETY ITEMS OF INTEREST

Men Wanted for Engineer Regiments

The following information is published here by request, so that members of the Society, even though they themselves may not be eligible, may make it known to those who are interested.

Enlisted men and non-commissioned officers are needed for the First Replacement Regiment of Engineers. This regiment was organized at Washington Barracks, D. C., on December 14th, 1917, for the express purpose of recruiting and training men to fill up depleted ranks in the regular Engineer Regiments, so that they may be kept at full strength during the period of the war.

The regiment will be required to furnish men for the following organizations:

Camouflage regiments; crane operating and maintenance regiments; depot detachments; electrical and mechanical regiments; forestry battalions; gas and flame service; general construction battalions; mining, quarry, and sapper regiments; searchlight regiments; supply and shop battalions; surveying and mapping regiments; water supply companies.

Few civilians know that it is possible for them to perform, in the Engineering Corps, almost exactly the same kind of work as that in which they are at present engaged. The best results, in any organization, are obtained only when the energies of all are concentrated along the lines for which they are best suited by natural ability, education, or training. It is more important to have the right man in the right place in our army, where the lives of men are at stake, than it is in any business enterprise.

The preliminary work of the recruit is a thorough training in military drill, for the engineer soldier must be prepared to drop his shovel and take up his rifle at any time. Infantry drills gradually give way to engineering work and more specific technical training. The men are taught all the important kinds of knots and lashings, how to build spar and truss bridges, to construct revetments, dig trenches, place wire entanglements, build machine-gun emplacements, pontoon bridges, and roads. They are also taught the methods of demolition, sapping, and mining. Special courses in lithography, surveying, mapping, photography, carpentry, blacksmithing, electricity, and machinery are also given to those qualified for further training in any of these subjects.

The range of work for which men are needed is so wide that practically every man with any technical training or mechanical ability can find a place in this organization.

Every male citizen of the United States who is physically fit, and is between the ages of 18 and 21, and 31 and 40, is eligible to join the regiment by voluntary enlistment.

The applicant should obtain the necessary application form from the Commanding Officer, 1st Replacement Regiment of Engineers, Room 107, Headquarters Building, Post of Washington Barracks, D. C. This form should be filled in and forwarded to the Commanding Officer. If the applicant is found to be eligible, an enlistment card is forwarded to the Recruiting Officer nearest to the applicant's place of residence, with instructions to enlist the man for service in the First Replacement Regiment of Engineers. Transportation and meals will be furnished by the Recruiting Officer, and the recruit will be instructed to report at the Post for duty.

It is important that the applicant comply with these instructions closely, as otherwise it may be found impossible to effect a transfer to the organization after enlistment.

ANNOUNCEMENTS

The Reading Room of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

May 1st, 1918.—8.30 P. M.—A regular business meeting will be held, and a paper by J. A. L. Waddell, M. Am. Soc. C. E., entitled "The Economics of Steel Arch Bridges", will be presented for discussion.

This paper was printed in *Proceedings* for March, 1918.

May 15th, 1918.—8.30 P. M.—At this meeting a paper by Vernon L. Sullivan, M. Am. Soc. C. E., entitled "Construction Methods Used in Building the Lower Reservoir Dam of the Balmorhea Project", will be presented for discussion.

This paper is printed in this number of *Proceedings.*

ANNUAL CONVENTION ABANDONED

The Board of Direction has decided that the Annual Convention of 1918 shall be abandoned, on account of War Conditions. Among the reasons for this action are: the absence of many members of the Society in the service of the country; the inappropriateness of social functions at this time; the limitation of transportation facilities; and the advisability of the practice of economy along all lines.

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction to the members who have made use of the resources of the Society in this manner has been expressed frequently, and leaves little doubt that if it were generally known to engineers that such assistance could be had, many would avail themselves of it.

On October 1st, 1916, the Library of the American Society of Civil Engineers ceased to exist as such, and was merged in the Engineering Societies Library, adding 67 000 volumes to the collection, which comprises also the former libraries of the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, and now has a total of 133 000 volumes and pamphlets. Containing, as the Library now does, the special collections mentioned, its scope is broadened, and, as it receives an unusually large number of technical periodicals, it is well equipped to continue the service formerly rendered by the Society Library.

The Engineering Societies Library offers this service at a cost which is trifling compared with the value of the time of an engineer who personally looks up such matters, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

It sometimes happens that references are found which are not readily accessible to the person for whom the search is made. In that case the Library is prepared to furnish photographic copies of the material at a small price per page. This method is particularly useful when there are drawings or figures in the text, which would be very expensive to reproduce by hand.

The Library is also able to provide translations of articles in foreign languages when desired.

Requests for searches, copies, translations, etc., should be addressed to the Director, Engineering Societies Library, 29 West 39th Street, New York City, who will gladly give information concerning the charges for the various kinds of service.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings.*

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion will be published as heretofore in *Proceedings,* and set down for presentation to a future meeting of the Society, and, on these, oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which from their mathematical or technical nature, in the opinion of the Committee, are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions only will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions.*

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 35 of the Year Book for 1918.

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association, Organized 1905.

Jerome Newman, President; Nathan A. Bowers, Secretary-Treasurer, 502 Rialto Building, San Francisco, Cal.

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Palace Hotel, on the third Tuesday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at noon, every Wednesday, at the Engineers' Club, 57 Post Street, where special tables are reserved for members and guests of the Association.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

Colorado Association, Organized 1908.

Robert Follansbee, President; L. R. Hinman, Secretary-Treasurer, 1400 West Colfax Avenue, Denver, Colo.

The meetings of the Colorado Association of Members of the American Society of Civil Engineers (Denver, Colo.) are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesday at 12.30 P. M., at Daniels and Fisher's.

Visiting members are urged to attend the meetings and luncheons.

Atlanta Association, Organized 1912.

B. M. Hall, President; W. C. Spiker, Secretary-Treasurer, 1408 Candler Building, Atlanta, Ga.

Baltimore Association, Organized 1914.

Mason D. Pratt, President; Charles J. Tilden, Secretary-Treasurer, The Johns Hopkins University, Baltimore, Md.

Cleveland Association, Organized 1914.

Harry Fuller, President; George H. Tinker, Secretary-Treasurer, 516 Columbia Building, Cleveland, Ohio.

(Abstract of Minutes of Meeting)

February 23d, 1918.—The meeting was called to order at 12.30 P. M., at the rooms of the Cleveland Engineering Society; Vice-President A. J. Hines in the chair; George H. Tinker, Secretary; and present, also, 17 members.

The minutes of the meeting of February 5th, 1918, were read and approved.

A communication from the State Civil Service Commission of Ohio, relative to a vacancy on the Board of Examinations, was read by the Secretary, and ordered posted on the bulletin board in the rooms of the Cleveland Engineering Society.

The Secretary read communications from the Colorado and Utah Associations in reference to the War Income Tax. Mr. B. R. Leffler reported for the Legislative Committee that he had communicated with all the associations of professional men in Cleveland relative to the subject and that the local chapter of the American Institute of Architects had agreed to co-operate to secure a repeal of Sections 200 and 209 of the law.

The proposed revision of the Constitution of the Society was discussed by Messrs. Mordecai, Himes, Leffler, Tinker, Thomas, Kinsley, Carter and W. P. Brown, but no action was taken.

The following resolution was introduced, and, after discussion by Messrs. Leffler, Hoffmann, Mordecai, and Tinker, was adopted:

"*Whereas,* There appears to be a difference of opinion concerning the wisdom and sufficiency of the proposed amendments to the constitution of the American Society C. E.; and

"*Whereas,* It seems probable that there will remain dissatisfaction whether the proposed amendments are adopted or rejected; therefore, be it

"*Resolved:* That the Cleveland Association of Members requests each of the local Associations of Members, American Society C. E., to appoint one delegate and one alternate to a Joint Association Constitutional Conference; said conference to consider the desirability and substance of further amendments, particularly with reference to a more democratic management of the Society, and report their deliberations from time to time to the Local Associations of Members."

Mr. Himes reported the organization, on January 29th, 1918, at Columbus, Ohio, of the Association of Ohio Technical Societies. He stated that ten societies were represented and that twelve are included in the Association; that resolutions were adopted giving the reasons for co-operation among the engineering organizations of Ohio, endorsing the ten principles of co-operation adopted by the Committee on Engineering Co-operation on March 30th, 1917, and the report of the Inter-Society Relation Committee of the Cleveland Engineering Society wherein it is suggested that "the National Societies consider as a prerequisite of membership that a candidate shall show membership in an accredited local society", and advising the appointment of an engineer on all boards and commissions having to do with public works.

On motion, duly seconded, it was decided to hang the Service Flag of the Association, which contains ten stars, suitably labeled, in the rooms of the Cleveland Engineering Society.

Adjourned.

Detroit Association, Organized 1916.

T. A. Leisen, President; Clarence W. Hubbell, Secretary, 2348 Penobscot Building, Detroit, Mich.

The regular meetings of the Association are held on the second Friday of December, April, and October, the last being the Annual Meeting.

District of Columbia Association, Organized 1916.

A. P. Davis, President; John C. Hoyt, Secretary-Treasurer, U. S. Geological Survey, Washington, D. C.

Duluth Association, Organized 1917.

F. E. House, President; Walter G. Zimmermann, Secretary, Wolvin Building, Duluth, Minn.

The regular meetings of the Association are held at noon on the third Monday of each month (usually at the Kitchi Gamma Club), with luncheon, followed by a short business session and the reading of papers. Visiting members of the American Society of Civil Engineers can secure from the Secretary definite information relating to the meetings, at which they will be welcomed. The Annual Meeting is held on the third Monday in May.

(Abstract of Minutes of Meeting)

March 25th, 1918.—The meeting was called to order at the Kitchi Gamma Club; Second Vice-President W. B. Patton in the chair; Walter G. Zimmermann, Secretary; and present, also 23 members and 5 guests.

The Association Papers of 1917 were distributed, and a motion to assess the cost on the members was passed.

A paper entitled "Double Mixing of Concrete", by A. M. Gow, Assistant Chief Engineer of the Oliver Mining Company, was presented by the author, and the subject was discussed by a number of the members present.

Adjourned.

Illinois Association, Organized 1916.

A. S. Baldwin, President; Edgar S. Nethercut, Secretary-Treasurer, 705 Michigan Ave., Evanston, Ill.

The regular meetings of the Association are held on the second Monday of March, June, September, and December, the last being the Annual Meeting. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary.

Louisiana Association, Organized 1914.

W. B. Gregory, President; Charles W. Okey, Secretary, Tulane University, New Orleans, La.

The regular meetings of the Association are held at The Cabildo, New Orleans, La., on the first Monday of January, April, July, and October.

Nebraska Association, Organized 1917.

George L. Campen, President; Homer V. Knouse, Secretary-Treasurer, 115 City Hall, Omaha, Nebr.

Regular meetings of the Association are held on the first Saturday of each month, except July and August, and at such places as may be appointed from time to time by the Executive Committee. The Annual Meeting is held in Lincoln, Nebr., on the second Friday in January.

An "Engineers' Round Table" is reserved daily for luncheons, at Courtenay's Restaurant, 17th and Douglas Streets, Omaha, to which all engineers are invited. Visiting members of the Society are especially urged to communicate with the Secretary when in the city.

Northwestern Association, Organized 1914.

P. E. Thian, President; Ralph D. Thomas, Secretary, 508 South First Street, Minneapolis, Minn.

The meetings of the Association are held bi-monthly, alternating between St. Paul and Minneapolis, on the third Friday of each month. Information as to the time and place of such meetings will be furnished on application to the Secretary.

Philadelphia Association, Organized 1913.

Henry H. Quimby, President; C. W. Thorn, Secretary, 1313 South Broad Street, Philadelphia, Pa.

The regular meetings of the Association are held at the Engineers' Club of Philadelphia, 1317 Spruce Street, on the First Monday in January, April, and October, the last being the Annual Meeting.

Pittsburgh Association, Organized 1917.

Richard Khuen, Jr., President; A. B. McGrew, Secretary-Treasurer, 2111 Farmers Bank Building, Pittsburgh, Pa.

The Annual Meeting of the Association is held on the first Monday in October. The time and place of other meetings are not fixed, but this information will be furnished on application to the Secretary.

(Abstract of Minutes of Meetings)

February 27th, 1918.—A dinner and smoker were held at the Fort Pitt Hotel. The meeting was called to order after the dinner; President Richard Khuen, Jr., in the chair; C. M. Reppert, Secretary; and present, also, more than 50 members at the dinner and more than 100 members and guests at the smoker.

The minutes of the meeting of January 9th, 1918, were read and approved.

President Khuen called for discussion of the proposed revision of the Constitution of the Society, inviting attention to the fact that letter-ballots for or against the revision would be canvassed on March 6th, 1918. There was no discussion.

Lt.-Commander Mansfield, U. S. N., addressed the meeting relative to the shipping situation and the desirability of naval control of American shipping.

An address on "The Necessity for Greater Co-operation Among Civil Engineers", was given by Herbert F. Snow, M. Am. Soc. C. E., Chief Engineer of the Public Service Commission of the State of Pennsylvania. Mr. Snow was followed by Mr. George Neilson who spoke in support of the desirability of such co-operation.

Adjourned.

March 11th, 1918.—At the meeting held at the Fort Pitt Hotel at 12.30 P. M., President Richard Khuen, Jr., in the chair, C. M. Reppert, Secretary, and present, also, about 40 members, an informal reception and luncheon was tendered Dr. A. N. Talbot, of Urbana, Ill., President of the Society.

After the reception, which afforded the members in attendance an opportunity to meet the President, luncheon was served.

After the luncheon Dr. Talbot addressed the meeting on the scope of the work of the Society, as well as that of the Engineering Council, of which he is a member. He endorsed heartily the organization of the Association, and congratulated its members on the enthusiasm and good fellowship shown at the luncheon.

President Khuen announced that C. M. Reppert, Secretary-Treasurer, had resigned, owing to removal from the city, and that Mr. A. B. McGrew had been appointed by the Executive Committee as his successor.

It was also announced that, by the action of the Executive Committee, all members of the Society in the Pittsburgh District, who are serving in the United States Army and Navy, will be classed as Honorary Members of the Association during the war and that such members will be exempt from dues.

Adjourned.

March 21st, 1918.—The meeting of the Association was preceded by an informal reception and dinner, in the Assembly Room of the Fort Pitt Hotel, in honor of the guests of the evening, who were Maj.-Gen. Charles M. Clement, U. S. A. (*Retired*), of Sunbury, Pa., Brig.-Gen. A. J. Logan, U. S. A. (*Retired*); Col. J. A. W. Brooks, U. S. A. (*Retired*); Lt.-Col. H. W. Stickle, U. S. A. (*Retired*); Lt.-Commander Newton Mansfield, U. S. N. (*Retired*); and Maj. Hilliard Lyle, Commandant, Carnegie Institute of Technology, all of Pittsburgh, Pa. There were present at the dinner, also, 43 members of the Association. Toasts were responded to by Gen. Logan, Col. Brooks, and Col. Stickle, interspersed with war songs by the Musical Committee.

The meeting was held in the Auditorium of the Chamber of Commerce; Vice-President R. A. Cummings in the chair; A. B. McGrew, Secretary; and present, also, about 500 members and guests.

The minutes of the meetings of February 24th and March 11th, 1918, were read and approved, as printed in the *Bulletin* of the Association for March, 1918.

Following the singing of the "Battle Hymn of the Republic", an address was delivered by Maj.-Gen. Clement, on his experience with the American Expeditionary Forces in France.

"America" was then sung, after which Maj. Lyle related his experiences with the Canadian Expeditionary Forces at the front. This address was followed by the singing of the "Star Spangled Banner".

A rising vote of thanks was tendered Maj. Clement and Maj. Lyle for their addresses.

Adjourned.

Portland, Ore., Association, Organized 1913.

Philip H. Dater, President; C. P. Keyser, Secretary, 1147 East Yamhill Street, Portland, Ore.

St. Louis Association, Organized 1888 (Constitution Approved by Board, 1914).

J. A. Ockerson, President; C. M. Daily, Secretary-Treasurer, 34 East Grand Avenue, St. Louis, Mo.

The Annual Meeting of the Association for the election of officers and for the transaction of business, is held on the fourth Monday in November. Two meetings each year, for the presentation and discussion of technical papers, are held in the Auditorium of the Engineers Club of St. Louis and are open to members of the Associated Societies. Other "get-together" meetings are held regularly for dinner or luncheon on the fourth Monday of each month except July, August, and November.

(Abstract of Minutes of Meeting)

March 25th, 1918.—The meeting was called to order at the City Club, at 12.30 P. M.; President Ockerson in the chair; C. M. Daily, Secretary; and present, also, 16 members.

Mr. Edward E. Wall presented some of the features of the Standard Form of Contract and Bond adopted by the American Institute of Architects, with the suggestion that it might be advisable for the Society to prepare and adopt a Standard Form of Contract and Bond suitable for use by the Engineering Profession.

On motion, duly seconded, it was decided that the Chairman appoint a committee of the Association to investigate the merits of a Standard Form of Contract and Bond and report at the next meeting. President Ockerson subsequently appointed Messrs. Wall, Greensfelder, and Sammelman as such committee.

The defeat of the proposed revision of the Constitution of the Society was discussed, and regret was expressed at the lack of interest, shown by the small vote, in such matters by a majority of the members.

Adjourned.

San Diego Association, Organized 1915.

N. B. Kellogg, President; J. R. Comly, Secretary-Treasurer, 4105 Falcon Street, San Diego, Cal.

Seattle Association, Organized 1913.

A. S. Downey, President; Phil. A. Franklin, Secretary, Care, City Engineer's Office, County-City Building, Seattle, Wash.

The regular monthly meetings and luncheons of the Association are held at the Frye Hotel, 3d Avenue and Yesler Way, at 12.15 P. M., on the last Monday of each month. All members, in any grade, of the American Society of Civil Engineers are cordially invited to attend the meetings when in the vicinity.

Southern California Association, Organized 1914.

H. Hawgood, President; H. W. Dennis, Secretary, 329 San Fernando Building, Los Angeles, Cal.

The Southern California Association of Members of the American Society of Civil Engineers (Los Angeles, Cal.) holds regular bi-monthly meetings with banquet, at Hotel Clark, on the second Wednesday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M., every Wednesday and the place of meeting may be ascertained from the Secretary.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in Los Angeles, and any such member will be gladly welcomed as a guest at any of the meetings or luncheons.

Spokane Association, Organized 1914.

J. C. Ralston, President; B. J. Garnett, Secretary, City Hall, Spokane, Wash.

The regular meetings of the Association are held on the second Friday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary.

Visiting members are invited to attend the meetings and luncheons.

Texas Association, Organized 1913.

R. C. Gowdy, President; J. H. Brillhart, Secretary, care, Mosher Mfg. Co., Dallas, Tex.

Utah Association, Organized 1916.

George L. Swendsen, President; H. S. Kleinschmidt, Secretary-Treasurer, 306 Dooly Building, Salt Lake City, Utah.

The Annual Meeting of the Association is held on the first Wednesday in April. The time of other meetings is not fixed, but this information will be furnished on application to the Secretary.

MINUTES OF MEETINGS OF SPECIAL COMMITTEES

Special Committee on Stresses in Railroad Track

March 20th, 1918.—The meeting was held at Chicago, Ill. Present, A. N. Talbot (Chairman), G. H. Bremner, W. J. Burton, Charles S. Churchill, W. C. Cushing, C. D. Gennett, Jr. (representing Robert W. Hunt), C. G. E. Larsson, A. F. Reichmann, and H. R. Safford.

The Chairman was asked to make a brief statement before the Convention of the American Railway Engineering Association concerning the Progress Report* and the more recent work of the Committee.

The tests on track with locomotives not properly counterbalanced were reported, and the future work of the Committee was considered.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms, and at all meetings:

American Institute of Electrical Engineers, 25 West Thirty-ninth Street, New York City.

American Institute of Mining Engineers, 25 West Thirty-ninth Street, New York City.

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* *Proceedings*, Am. Soc. C. E., January, 1918, p. 55.

American Society of Mechanical Engineers, 25 West Thirty-ninth Street, New York City.

Assoçiacão dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 176 Mansfield Street, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, Public Library, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Detroit Engineering Society, Detroit Board of Commerce Building, Detroit, Mich.

Engineering Association of Nashville, Commercial Club Building, Nashville, Tenn.

Engineering Association of New South Wales, 5 Elizabeth Street, Sydney, New South Wales, Australia.

Engineering Societies Club of Hawaii, E. F. Cykler, Secretary, Honolulu, Hawaii.

Engineers and Architects Club of Louisville, 1412 Starks Building, Louisville, Ky.

Engineers' Club of Baltimore, 6 West Eager Street, Baltimore, Md.

Engineers' Club of Kansas City, Robert S. Beard, Secretary, Third Floor, City Hall, Kansas City, Mo.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Club of Trenton, Trent Theatre Building, 12 North Warren Street, Trenton, N. J.

Engineers' Society of Northeastern Pennsylvania, 415 Washington Avenue, Scranton, Pa.

Engineers' Society of Pennsylvania, 31 South Front Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 568 Union Arcade Building, Pittsburgh, Pa.

Florida Engineering Society, J. R. Benton, Secretary, Gainesville, Fla.

Institute of Marine Engineers, The Minories, Tower Hill, London, E., England.

Institution of Civil Engineers, Great George Street, Westminster, S. W., London, England.

Institution of Engineers of the River Plate, Calle 25 de Mayo 195, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, State Museum Building, Chartres and St. Ann Streets, New Orleans, La.

Memphis Engineers' Club, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Montana Society of Engineers, Butte, Mont.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Oregon Society of Civil Engineers, Portland, Ore.

Pacific Northwest Society of Engineers, 803 Central Building, Seattle, Wash.

Rochester Engineering Society, Rochester, N. Y.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Sociedad de Ingenieurs Civils de France, 19 rue Blanche, Paris, France.

Society of Engineers, 17 Victoria Street, Westminster, S. W., London, England.

Southwestern Society of Engineers, C. E. Barglebaugh, Secretary, 703 First National Bank Building, El Paso, Tex.

Svenska Teknologforeningen, Brunkebergstorg 18, Stockholm, Sweden.

Tekniske Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Vermont Society of Engineers, George A. Reed, Secretary, Montpelier, Vt.

Western Society of Engineers, 1735 Monadnock Block, Chicago, Ill.

ACCESSIONS TO THE ENGINEERING SOCIETIES LIBRARY

(From March 1st to April 1st, 1918)

DONATIONS*

The statements made in these notices are taken from the books themselves, and this Society is not responsible for them.

TECHNICAL MECHANICS:

Statics and Dynamics. By Edward R. Maurer. 4th ed., rev. and enl. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 381 pp., 178 illus., 9 x 6 in., cloth. $2.50.

A book on theoretical mechanics written for students of engineering, in which each subject discussed has a direct bearing on some engineering problem. The book thus differs from those commonly called Theoretical Mechanics, which are generally intended for students of mathematics or physics. It is, on the other hand, dissimilar to books commonly entitled Applied Mechanics. The fourth edition differs from the third by the addition of 176 more problems and the modification of the articles on axle reactions, efficiency of machines, hoists, gyrostats, kinetics of plane motion, rolling resistance, kinetics of a body with a fixed point, and the dynamics of any motion of a rigid body.

THE CALORIFIC POWER OF FUELS:

With a Collection of Auxiliary Tables and Tables Showing the Heat of Combustion of Fuels, Solid, Liquid, and Gaseous. By Herman Poole. 3d ed., rewritten by Robert Thurston Kent. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1918. 10 + 267 pp., 65 illus., 9 x 6 in., cloth. $3.00.

The introduction of new fuels, the improvements in the methods of investigating the calorific power of fuels, and the increase in available accurate data have made it necessary to rewrite the book. The latest researches have been incorporated, inaccurate data occurring in earlier editions have been eliminated, and the results have generally been reported in the English system of units instead of in the metric system used in former editions.

THE GAS ENGINE HANDBOOK:

A Manual of Useful Information for the Designer and the Engineer. By E. W. Roberts. 9th ed., rewritten and enl. Cincinnati, The Gas Engine Publishing Co. (copyright 1917). 315 pp., 80 illus., 7 x 5 in., leather. $2.00.

An epitome of gas engine practice, in pocket-book form, intended as a handy book of reference. This ninth edition has been revised to show present practice. Contents: Descriptive; Design; Operation, Testing, Selection.

GAS, GASOLINE AND OIL ENGINES:

A Complete, Practical Work Defining Clearly the Elements of Internal Combustion Engineering. Treating Exhaustively on the Design, Construction and Practical Application of all Forms of Gas, Gasoline, Kerosene and Crude Petroleum-Oil Engines. Describes Minutely all Auxiliary Systems, such as Lubrication, Carburetion, and Ignition. Considers the Theory and Management of all Forms of Explosive Motors for Stationary and Marine Work, Automobiles, Aeroplanes and Motorcycles; Includes also Producer Gas and its Production. By Gardner D. Hiscox. Revised, Enlarged, and Brought up to Date by Victor W. Pagé. 22d ed. N. Y., The Norman W. Henley Publishing Co., 1918. 640 pp., 435 illus., 9 x 6 in., cloth. $2.50.

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* Unless otherwise specified, books in this list have been donated by the publishers.

The present edition of this well known work has been very thoroughly revised throughout, and an attempt has been made to include all recent developments of importance. New tables, formulas and illustrations have been included, and obsolete material has been eliminated, except when of historical interest.

BROWN'S DIRECTORY OF AMERICAN GAS COMPANIES, 1917.

Compiled and Corrected Annually by E. C. Brown. N. Y., The Gas Age, 1917. 897 pp., 11 x 7 in., cloth. $5.00.

This edition summarizes the statistics of 1179 manufactured, 768 natural, 134 acetylene, and 70 gasoline gas companies, 161 parent or operating companies and 47 public service commissions. An appendix includes the financial data of 277 companies, the officers, directors, and committees of gas associations and an alphabetical list of gas association members, with their company and association affiliations.

BROACHES AND BROACHING.

By Ethan Viall. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1918. 221 pp., 188 illus., 9 x 6 in., cloth. $2.00.

A summary of the present development of broaching work and machinery, written primarily to enable those interested to judge whether it is applicable to their particular class of work or not, and to provide working directions in the former case. Contents: Broaching and Broaching Tools; Standard Types of Broaching Machines; Examples of Pull Broaching Work and Practice; Examples of Push Broaching Work and Practice; The Design of Pull Broaches; The Design of Push Broaches; Making Broaches.

AUTOMOBILE WELDING WITH THE OXY-ACETYLENE FLAME:

A Practical Treatise Covering the Repairing of Automobiles by Welding, with a Non-Technical Explanation of the Principles to be Guided by in the Successful Welding of the Various Metals. By M. Keith Dunham. N. Y., The Norman W. Henley Publishing Co., 1917. 167 pp., 66 illus., 6 x 4 in., cloth. $1.00.

A manual for workmen which explains in simple language the principles of welding, and describes in detail their application in automobile repairing.

OXY-ACETYLENE WELDING PRACTICE:

A Practical Presentation of the Modern Processes of Welding, Cutting, and Lead Burning, with Special Attention to Welding Technique for Steel, Cast Iron, Aluminum, Copper and Brass. By Robert J. Kehl. Chic., American Technical Society, 1918. 102 pp., 111 illus., 8 x 5 in., cloth. $1.00.

A well illustrated description of the methods and appliances in use, intended for the workman and superintendent. Contents: Welding Processes; Technique of Oxy-Acetylene Welding; Miscellaneous Oxy-Acetylene Processes; Examples of Automobile Repair; Costs.

REFERENCE NOTES FOR USE IN THE COURSE IN GUNNERY

And Ammunition, Coast Artillery School. 3d ed. Fort Monroe. Coast Artillery School Press, 1917. 123 pp., 19 illus., 9 x 6 in., paper. 50 cents.

A brief textbook compiled to meet the immediate demands of candidates for commissions in the Second Coast Artillery School at Fort Monroe.

NOTES ON BALLISTICS:

Direct Fire; by Capt. George A. Wildrick. High Angle Fire; by Lt.-Col. Alston Hamilton. 2d ed. Fort Monroe, Journal, U. S. Artillery, 1917. 99 pp., 9 illus., 2 diagrams, 10 x 6 in., paper. 50 cents.

Capt. Wildrick's paper treats of the problems that are most likely to be encountered at the battery, showing current methods of applying ballistic data to their solution. Lt.-Col. Hamilton presents the formulas and methods used in ordinary ballistic computations for high-angle fire.

MUSKETRY:

(0.303 and 0.22 Cartridges), Elementary Training, Visual Training, Judging Distances, Fire Direction and Control, Range Practices, Individual and Collective Field Practices; by Capt. E. J. Solano. Hand Grenades; Their Construction—Mills, Hales, Pippin Rifle Grenade, Service, Vaneless, Mexican or Tonite, "P" Grenade, Jam Pot, Hair Brush, etc.; by Capt. S. A. Dion. Am. ed. N. Y., George U. Harvey Publishing Company, Inc., 1917. 258 pp., 72 illus., 5 x 4 in., linen. $1.00.

A pocket-size book manual for officers and men.

HANDBOOK FOR THE 0.303-INCH VICKERS MACHINE GUN:

(Magazine Rifle Chamber), Mounted on Tripod Mounting, Mark IV. N. Y., George U. Harvey Publishing Co., Inc., 1917. 82 pp., 1 pl., 5 x 3 in., linen. 50 cents.

A catalogue in pocket size for those who are called on to use this gun, written by a British Army Officer and edited by Capt. S. A. Dion.

A BIBLIOGRAPHY OF THE WAR CRIPPLE.

Compiled by Douglas C. McMurtrie. The Economic Consequences of Physical Disability; A Case Study of Civilian Cripples in New York City; by John Culbert Faries. Memorandum on Provision for Disabled Soldiers in New Zealand; by Douglas C. McMurtrie. N. Y., Red Cross Institute, 1918. 11 x 8 in., paper.

These pamphlets form the first three numbers of the Publications of the Red Cross Institute for Crippled and Disabled Men, a series edited by Mr. McMurtrie. The bibliography covers 39 pages and will be further extended by supplements as new material accumulates.

THE PETROLEUM AND NATURAL GAS REGISTER:

A Directory of the Petroleum and Natural Gas Industries in the United States, Canada, and Mexico. 1917-1918 ed. N. Y., The Oil Trade Journal. 548 pp., 12 x 9 in., cloth. $10.00.

Includes in one directory material on all branches of the petroleum and natural gas industry. The work is based on statements made by officials of the companies listed, and gives the usually needed information as to properties, capital stock, officers, etc.

FARM FORESTRY.

By John Arden Ferguson. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1916. 233 pp., 5 illus., 40 pl., 8 x 5 in., cloth. $4.25.

A text-book on the care and management of farm woodlots and the utilization of their products, intended for use by students in agricultural colleges.

ESSENTIALS OF VOLUMETRIC ANALYSIS:

An Introduction to the Subject, Adapted to the Needs of Students of Pharmaceutical Chemistry. Embracing the Subjects of Alkalimetry, Acidimetry, Precipitation Analysis, Oxidimetry, Indirect Oxidation, Idometry, Assay Processes for Drugs, Estimation of Alkaloids, Phenol, Sugars, Theory, Application and Description of Indicators. By Henry W. Schimpf. 3d ed., rewritten and enl. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 14 + 366 pp., 61 illus., 8 x 6 in., cloth. $1.60.

This edition is revised to accord with the new United States Pharmacopœia, and improved by the additions of many new assay methods.

A SHORT HANDBOOK OF OIL ANALYSIS.

By Augustus H. Gill. 8th ed., rev. Phila. and Lond., J. B. Lippincott Co. (copyright 1918). 209 pp., 9 illus., 8 x 5 in., cloth.

This well-known manual is designed to provide a concise account of the methods of applying the usual physical and chemical tests to oils. The eighth edition has been revised, descriptions of some new forms of apparatus have been included and some minor tests and new methods added.

AIDS IN THE COMMERCIAL ANALYSIS OF OILS, FATS,

And Their Commercial Products; a Laboratory Handbook. By George Fenwick Pickering. Phila., J. B. Lippincott Co.; Lond., Charles Griffin and Co., 1917. 133 pp., 9 x 6 in., cloth.

Intended as a guide in works laboratories. The tests for determining the purity of the substances and their suitability for various purposes are given, together with tables of constants for each. These values, the author states, are here published for the first time.

THE PHYSICAL CHEMISTRY OF THE PROTEINS.

By T. Brailsford Robertson. N. Y. and Lond., Longmans, Green & Co., 1918. 15 + 483 pp., 8 illus., 9 x 6 in., cloth. $5.00.

An endeavor to interpret the physico-chemical behavior of the proteins in the light of the laws of Boyle and of Gay-Lussac, as they have been applied to solutions by Vant't Hoff, and of the Guldberg and Waage Mass-law. Although confined to proteins, the work is a contribution to an analyses of the properties and behavoir of colloids in general. Rewritten from the German edition of 1912, with references to the literature to the middle of 1917.

THE CHEMICAL CONSTITUTION OF THE PROTEINS.

By R. H. A. Plimmer. Part 1, Analysis. N. Y. and Lond., Longmans, Green and Co., 1917. 12 + 174 pp., 7 illus., 10 x 6 in., boards. $1.80.

A thorough revision of the earlier editions, with which much new matter has been incorporated. This section discusses the chemical composition of the protein molecule, and is mainly connected with the analysis of proteins. A very complete bibliography is included.

CHEMICAL PATENTS

And Allied Patent Problems. By Edward Thomas. Washington, John Byrne & Co., 1917. 58 pp., 9 x 6 in., cloth. $2.50.

This work is intended to provide a statement of the law of chemical patents, together with a practically complete list of the cases on which it is based, and of the principal cases intimately related in reasoning to them. Written from the point of view of the patent attorney and the expert witness.

A MANUAL OF THE PROCESSES OF WINDING, WARPING, AND QUILLING

Of Silk and Other Various Yarns from the Skein to the Loom. By Samuel Kline. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1918. 134 pp., 20 illus., 8 x 5 in., cloth. $2.00.

The preface announces this as the first American reference book on the technique of these branches of textile manufacture, and states that it is based on long practical experience.

DYES AND DYEING.

By Charles E. Pellew. N. Y., Robert M. McBride & Company, 1918. 274 pp., 24 illus., 3 pl., 8 x 5 in., cloth. $2.00.

This book describes the modern dyes in non-technical language, discusses the theory and practice of color dyeing, and describes the methods of dyeing various fabrics and materials. Various methods of coloring objects in patterns are also described. It is intended for use by craftsmen doing small scale work, rather than for professional dyers or dye-house chemists.

A SUPPLEMENTARY MEMOIR ON BRITISH RESOURCES OF SANDS

And Rocks Used in Glass-Manufacture; With Notes on Certain Refractory Materials. By P. G. H. Boswell, with Contributions by W. B. Wright, H. F. Harwood, and A. A. Eldridge. N. Y. and Lond., Longmans, Green and Co., 1917. 85 pp., 7 pl., 8 x 6 in., paper. $1.00.

Supplements the memoir of the same title which was published in 1916. Describes further supplies and treatment of materials, so that the study of British resources of glass-sand is now believed to be fairly exhaustive. A chapter on American high-grade sands is included.

MONTHLY COST ACCOUNTING FOR VARNISH PLANTS.

By E. W. Story. Phila., National Varnish Manufacturers Association (copyright 1917). 51 pp., 9 x 6 in., paper. $1.25.

A detailed description of a method prepared at the request of the National Varnish Manufacturers Association, which the author believes will be adaptable to any varnish business.

THE ELEMENTS OF RAILROAD ENGINEERING.

By William G. Raymond. 3d ed., rev. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 24 + 453 pp., 107 illus., 9 x 6 in., cloth. $4.00.

This book attempts to describe the fixed portion of a railroad plant and to give the underlying principles of the design of its layout. The present edition has been largely revised, and the introduction has been modified to conform to the progress that has been made in the study of valuation and regulation of utilities, the discussion of engine capacity and the chapters on signaling have been rewritten, and a chapter on the principles of valuation has been added. Contents: Introduction; Permanent Way; The Locomotive and Its Work; Railroad Location, Construction and Betterment Surveys; Appendix.

RAILROAD STRUCTURES AND ESTIMATES.

By J. W. Orrock. 2d ed., rev. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1918. 579 pp., 272 illus., 9 x 6 in., flexible cloth. $5.00.

The author has re-arranged the chapters in this edition to conform approximately with the classification of accounts as prescribed by the Interstate Commerce Commission in 1914, changed the prices to those which ruled in normal times, previous to 1915, added much new material, and, wherever possible, has given unit costs for all items of track work, track structures, and buildings. A feature is made of quantities for track material.

A Handbook for Practitioners of Medicine. By Fletcher Gardner. St. Louis, C. V. Mosby Company, 1916. 418 pp., 46 illus., 9 x 6 in., cloth. $4.00.

This handbook is intended to provide, in a single volume, a plain non-technical exposition of the duties of a health officer by one familiar with his needs and experienced in the routine and emergencies of the local sanitary service. The second edition is thoroughly revised. An appendix gives schemes for sanitary surveys of cities, public buildings, and schools.

THE EXAMINATION OF MILK FOR PUBLIC HEALTH PURPOSES.

By Joseph Race. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1918. 224 pp., 4 illus., 8 x 5 in., cloth. $1.75.

This volume is primarily intended as a practical handbook for those engaged in the chemical and bacteriological examination of milk. Numerous references to the literature are included.

MECHANICAL EQUIPMENT OF SCHOOL BUILDINGS.

By Harold Alt. Milwaukee, The Bruce Publishing Co. (copyright 1916). 111 pp., 160 illus., 11 x 8 in., cloth. $2.50.

A discussion of the various problems which arise in the design and installation of the equipment for ventilating, heating, lighting, sewage disposal, cleaning, toilets, drinking water, fire protection, etc., by an engineer with experience as a designing and supervising engineer.

FRESH-WATER BIOLOGY.

By Henry Baldwin Ward and George Chandler Whipple, With the Collaboration of a Staff of Specialists. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1918. 1111 pp., 1547 illus., 9 x 6 in., cloth. $6.00.

An important attempt to cover North American fresh-water life in its entirety in a single volume. In addition to chapters handled by a specialist on each group, there are chapters on general biological topics, and one on the technical and sanitary problems of the subject.

RELIEF FROM FLOODS;

The Fundamentals of Flood Prevention, Flood Production, and the Means for Determining Proper Remedies. By John W. Alvord and Charles B. Burdick. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1918. 175 pp., 53 illus., 9 x 6 in., cloth. $2.00.

The authors of this book have not attempted a treatise on flood relief, but have tried to outline briefly the general flood problem in all its many phases, to show what remedies can be applied, and to point the way to the selection of the proper works. Technicalities have been avoided, with the hope that the matter may be understandable to readers who are not engineers. A table of great floods is given in the appendix.

ROLL OF HONOR

A List of Members of the Society Who are Serving in the Army or Navy of the United States or Any of Its Allies.*

Abbot, Frederic V. Brig.-Gen., Corps of Engrs., N. A., Office, Chief of Engrs., U. S. A., Washington, D. C.

Abbot, Frederick William. Lt.-Col., British Army; Metropolitan Club, New York City.

Acher, A. H. Maj., Corps of Engrs., U. S. A., 4th Engrs., Camp Greene, N. C.

Ackerman, Alexander S. 1st Lieut., Engrs., U. S. R.; 11 Francis St., Newport, R. I.

Ackerman, Arthur P. 1st Lieut., U. S. R., 33d Engrs.; Great Barrington, Mass.

Adams, Arthur. Maj., Ord., U. S. R., 6th and B Sts., N. W., Washington, D. C.

Adams, Edward M. Maj., U. S. A., Care, The Adjt.-Gen., U. S. A., Washington, D. C.

Adams, Milton Jewell. Capt., U. S. R., Co. C, 114th Engrs., Camp Beauregard, Alexandria, La.

Adams, Raymond E. Capt., Q. M. C., U. S. R., Asst. to the Q. M., S. E. D., Peoples Bldg., Charleston, S. C.

†**Agnew, Augustus Waterous.** Capt., 3d Canadian Pioneers.

Albert, Frederick W. Maj., U. S. R., 33d Engrs.; 23 Isham St., Burlington, Vt.

Alden, Herbert C. 1st Lieut., C. A. C., N. G. U. S., Fort Schuyler, N. Y.

Alexander, E. Porter. 1st Lieut., U. S. R., 509th Engrs., Fort Sam Houston, San Antonio, Tex.

Alexander, Kay. Maj., 2d in Command, 12th Canadian Ry. Troops, B. E. F., France.

Allen, Franklin R. Capt., Engrs., U. S. R., 8th Co., E. R. O. T. C., Camp Lee, Va.

Allen, Herschel Heathcote. Capt., Engrs., U. S. R.; Instr., Camp Lee, Petersburg, Va.

Allen, Ralph B. 1st Lieut., U. S. R., Co. B, 25th Engrs., Am. Exp. Force, France.

Allen, Walter Henry. Maj., Engrs., U. S. R.; 1112 East Jefferson St., Bloomington, Ill.

Allen, Walter Hinds. Civ. Engr., U. S. N. (rank of Lt.-Commander); Public Works Officer, Naval Training Station, Great Lakes, Ill.

Allison, William F. Maj., Engrs., U. S. R., Am. Exp. Force, France.

Altman, Frank S. Lieut., U. S. R., 23d Engrs.; Atchison, Kans.

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* This list is made up from replies to a circular forwarded to members of the Society, and others, and is probably neither accurate nor complete. It is requested that the attention of the Secretary be called to any omissions or inaccuracies in order that they may be corrected in subsequent lists.

† Died in France.

Altstaetter, F. W. Col., Corps of Engrs., U. S. A., U. S. Engr. Office, Grand Rapids, Mich.

Anderson, J. E. Maj., 212th Field Co., Royal Engrs., B. E. F., France.

Anderson, J. H. Capt., U. S. R.; Adjt., 1st Replacement Engrs., Washington Barracks, Washington, D. C.

Anderson, W. P. Capt., Engrs., U. S. R., Am. Exp. Force, France.

Andrew, Clarence R. Capt., U. S. R., 32d Engrs., Camp Grant, Rockford, Ill.

Andrews, Carl B. Capt., Engrs., U. S. R. (*Unassigned*); 743 Wyllie St., Honolulu, Hawaii.

Andrews, J. H. M. Maj., Ord., U. S. R.; Commanding Officer, Raritan River Ordnance Depot, Metuchen, N. J.

Angas, Robert M. 1st Lieut., U. S. N. G., 106th Engrs., Camp Wheeler, Macon, Ga.

Annear, E. H. Capt., U. S. R., 20th Engrs., Camp American University, Washington, D. C.

Applegarth, Gault. Capt., U. S. R., 23d Engrs., Care, War Dept., Washington, D. C.

Ardery, Edward Dahl. Lt.-Col., Corps of Engrs., U. S. A., Am. Exp. Force, France.

Armitage, George W. Capt., Q. M. C., U. S. R.; Asst. to Dept. Q. M., Hawaiian Dept., Honolulu, Hawaii.

Arms, Leo M. 2d Lieut., U. S. R., 308th Engrs., Camp Sherman, Chillicothe, Ohio.

Armstrong, Charles Johnstone. Brig.-Gen.; Chf. Engr., H. Q., Canadian Army Corps, B. E. F., France.

Armstrong, Merwin. Capt., U. S. R., 105th Engrs., 30th Div., Camp Sevier, Greenville, S. C.

Arn, William G. Capt., U. S. R., 1st Bn., 13th U. S. Engrs. (Ry.), Am. Exp. Force, France.

Ashkins, Nathan Thomas. 1st Lieut., Engrs., U. S. R., Lines of Communication, Eng. Headquarters, Am. Exp. Force, France.

Ashley, Carl. Capt., Engrs., U. S. R., U. S. Military P. O. 702, Am. Exp. Force, France.

Ashmead, P. H. Maj., Engrs., U. S. R.; 35 Nassau St., New York City.

Asplundh, E. T. Capt., U. S. R.; Supply Officer, 103d Engrs., 28th Div., U. S. N. G., Camp Hancock, Augusta, Ga.

Asserson, Henry Raymond. Maj., Engrs., U. S. R., C. E. L. O. C., Am. Exp. Force, France.

Atterbury, W. W. Brig.-Gen.; Director of Transportation, Am. Exp. Force, France.

Atwood, William G. Maj., U. S. R., 17th Engrs. (Ry.), Am. Exp. Force, France, Care, Adjt. Gen., Washington, D. C.

Austill, Hurieosco. Capt., U. S. R., Co. D, 501st Engr. Service Bn., Am. Exp. Force, France.

Ayres, Quincy C. 2d Lieut., Engrs., U. S. R., Am. Exp. Force, France.

Babbitt, Harold E. Capt., Engrs., U. S. R., Chf. Engr.'s Office, Adv. Sect. S. O. R., U. S. P. O. No. 714, Am. Exp. Force, France.

Baffrey, Charles R. Capt., 102d Reg. d'Artillerie (French Army), Secteur Postal 160, B. C. M., Paris, France.

Bailey, Lewis P. Capt., U. S. R., Co. A, 304th Engrs., Camp Meade, Baltimore, Md.

Bakenhus, R. E. Civ. Engr., U. S. N. (rank of Commander), Bureau of Yards and Docks, Washington, D. C.

Baker, H. S. Lt.-Col., N. A., 111th Engrs., Camp Bowie, Fort Worth, Tex.

Baker, Shirley. Capt., U. S. R., Co. B, 23d Engrs., Camp Meade, Md.

Balch, William H. Capt., Engrs., U. S. R., A. P. O. 712, Am. Exp. Force, France.

Bandy, Edward L. 1st Lieut., Engrs., U. S. R., Camp American University, Washington, D. C.

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Barber, Justin F. Sergeant, Co. M, 23d Engrs., Laurel, Md.

Barber, Norman N. 1st Lieut., U. S. R., 6th Engrs., Am. Exp. Force, France.

Barclay, A. J. 1st Lieut., Engrs., U. S. R., Fort Leavenworth, Kans.

Barney, Samuel E. Maj., Engrs., U. S. R. (*Unassigned*); 346 Whitney Ave., New Haven, Conn.

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Bascom, George R. Maj., San. Corps, U. S. A., Fort Oglethorpe, Ga.

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Beall, Pendleton. Private, Headquarters Co., 165th Inf., Am. Exp. Force, France.

Beam, Carl Eugene. Co. E, 316th Engrs., Camp Lewis, American Lake, Wash.

Bebb, Edward C. Capt., Engrs., U. S. R., U. S. Geological Survey, Washington, D. C.

Beeman, Thomas R. Capt., Engrs., U. S. R., Am. Exp. Force, France.

Beerbower, Dumont. 1st Lieut., Engrs., U. S. R.; Asst. Instr., Co. 1, E. R. O. T. C., Camp Lee, Petersburg, Va.

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Behrman, I. E. 1st Lieut., Engrs., U. S. R., Care, C. E. O., Zone of the Advance, Am. Exp. Force, France.

Belknap, Francis W. Engrs., U. S. R., U. S. Army P. O. 705, Am. Exp. Force, France.

Bell, George Edward. Lieut., Canadian Engrs., Care, Bank of Montreal, Waterloo Pl., London, S. W., England.

Bellinger, L. F. Civ. Engr., U. S. N. (rank of Commander), U. S. Navy Yard, Bremerton, Wash.

Belzner, Theodore. 1st Lieut., Engrs., U. S. R. (*Unassigned*); 574 West 176th St., New York City.

Benham, Claude Gilbert. Capt., C. A. C., U. S. A., 800 Park Ave., Norfolk, Va.

Benham, W. L. Maj., Q. M. C., U. S. R.; Engr. Officer in Chg. of Camp Utilities, Camp Funston, Fort Riley, Kans.

Bennison, Ernest William. 1st Lieut., U. S. R., 23d Engrs., Camp Meade, Md.

Bensel, J. A. Maj., Engrs., U. S. R., Engr. Depot, Norfolk, Va.

Benson, Orville. Maj., Engrs., U. S. R., Headquarters, Am. Exp. Force, France.

Berdeau, Ray W. Capt., Engrs., U. S. R.; Asst. Div. Engr., 82d Div.

Betts, Clifford A. 1st Lieut., C. A. C., U. S. R., Am. Exp. Force, France.

Biddle, John. Maj.-Gen., Corps of Engrs., U. S. A.; Asst. Chf. of Staff, U. S. A., War Dept., Washington, D. C.

Billings, A. W. K. Lt.-Commander, Care, Commander, U. S. Naval Aviation Forces, Paris, France.

Billings, Fred M. Capt., Engrs., U. S. R., Camp Lee, Petersburg, Va.

Binckley, George Sydney. Maj., U. S. R., 112th Engrs., Montgomery, Ala.

Binger, Walter D. 2d Lieut., Sig. R. C.; 280 Madison Ave., New York City.

Birdseye, Claude H. Maj., Engrs., U. S. R., Coast Artillery Brigade, Am. Exp. Force, France.

Bishop, Roy P. 2d Lieut., U. S. R., 35th Engrs., Camp Grant, Rockford, Ill.

Bither, T. A. Lieut., Sig. R. C., A. S., Aviation School, Rockwell Field, San Diego, Cal.

Bixby, William H. Brig.-Gen., U. S. A. (*Retired*), 428 Customhouse, St. Louis, Mo.

Black, Dudley F. Capt., Engrs., U. S. R., 513th Service Bn., Camp Travis, Tex.

Black, G. G. Capt., Engrs., U. S. R.; Acting Adjt., 314th Engrs., Camp Funston, Fort Riley, Kans.

Black, James B. 1st Lieut., Engrs., U. S. R., Chf. Engr.'s Office, Headquarters, Am. Exp. Force, France.

Black, Ralph P. 1st Lieut., U. S. R., 32d Engrs., Camp Grant, Rockford, Ill.

Black, Roger Derby. Lt.-Col., Corps of Engrs., U. S. A., Headquarters, Am. Exp. Force, France.

Black, William M. Maj.-Gen.; Chf. of Engrs., U. S. A., War Dept., Washington, D. C.

Blackman, J. W. B. Lieut., Canadian Ry. Troops, Canadian Expeditionary Force.

Blair, Alexander. 2d Lieut., Royal Engrs., B. E. F., France.

Blair, McCrea Parker. Capt., No. 1 Depot Bn., Manitoba Reg., Winnipeg, Man., Canada.

Blanchard, Murray. Maj., U. S. R., 28th Engrs., Camp Meade, Admiral, Md.

Boesch, Clarence E. Capt., U. S. N. G., Co. B, 105th Engrs., Camp Sevier, Greenville, S. C.

Boggs, F. C. Col., 315th Engrs., N. A., Camp Travis, San Antonio, Tex.

Boland, Charles J. 1st Lieut., Sig. C., U. S. A., 80th Aero Squadron, Am. Exp. Force, France.

Bolin, Harry W. Sergeant, Co. E, 23d Engrs., Camp Meade, Annapolis Junction, Md.

Bond, P. S. Col., 107th Engrs., N. A.; Div. Engr., 32d Div., Army Engr. School, U. S. P. O. 714, Am. Exp. Force, France.

Bonner, John P. Capt., C. A. C., U. S. R., Am. Exp. Force, France.

Boorman, Kitchell M. Lieut., Sig. C., U. S. A., 481st Aero Squadron, Aviation Branch, Morrison, Va.

Booth, Raymond. 1st Lieut., Engrs., U. S. R., E. R. O. T. C., Camp Lee, Petersburg, Va.

Booz, Horace Corey. Col., R. T. C., N. A., Care, D. G. T., Am. Exp. Force, France.

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Wallace, Harold U. Maj., Engrs., N. A.

Waller, Percy. Capt., Engrs., U. S. R., Camp Lee, Petersburg, Va.

Walton, H. B. Capt., U. S. R., 312th Engrs., Camp Pike, Little Rock, Ark.

Ward, George S. 2d Lieut., U. S. R., Co. A, 117th Engrs., Am. Exp. Force, France.

Ward, Jasper D. Corporal, Co. C, 55th Inf., Chickamauga Park, Chattanooga, Tenn.

Ward, Lyman Wise. Capt., C. A. C., U. S. R., Battery E, 63d Artillery, Fort Flagler, Wash.

Ware, Howard T. 2d Lieut., Q. M. C., N. A., Bakery Co. No. 317, Camp Doniphan, Okla.

Ware, John. 1st Lieut., Co. A, 101st Engrs., Am. Exp. Force, France.

Ware, Norton. Capt., Engrs., U. S. R., Am. Exp. Force, France.

Warfield, Ralph M. Civ. Engr., U. S. N. (rank of Lt.-Commander), Navy Aeronautic Station, Pensacola, Fla.

Waring, C. T. Maj., Sig. R. C., Constr. Div., Langley Field, Hampton, Va.

Warner, Elwin S. Capt., U. S. R., Co. B, 301st Engrs., Camp Devens, Ayer, Mass.

Warren, James G. Col., Corps of Engrs., U. S. A., 540 Federal Bldg., Buffalo, N. Y.

Warren, Minton M. 1st Lieut., U. S. R., Headquarters Co., 101st Engrs., 51st Brigade, 26th Div., Am. Exp. Force, France.

Warren, Philip R. Maj., Royal Engrs., P. C. E., A. P. O. S. 10, B. E. F., France.

Watkins, Guy A. Capt., Engrs., U. S. R., Fort Sill, Okla.

Watson, D. M. Lieut., M. T., A. S. C., 100th Siege Battery, R. G. A., B. E. F., France.

Watson, George L. Capt., U. S. R., Co. B, 30th U. S. Engrs., Am. Exp. Force, France.

Watson, Winslow B. Lieut., Co. C, 7th N. Y. Inf. (114th), Camp Wadsworth, Spartanburg, S. C.

Waugh, William H. Capt., Engrs. U. S. R.; Pres. and Engr. Officer, Alaska Road Comm. and Senior Highway Engr., Office of Public Roads and Rural Eng., Juneau, Alaska.

Way, W. F. Sergeant, Co. D, 18th Engrs. (Ry.), U. S. Army Post Office No. 705, Am. Exp. Force, France.

Weaver, C. J. 1st Lieut., Engrs., U. S. R., Am. Exp. Force, England.

Weaver, Earll Chase. Asst. Civ. Engr., U. S. N. R. F., Navy Yard, Puget Sound, Wash.

Weaver, Frank L. 1st Lieut., 305th Engrs., Camp Lee, Petersburg, Va.

Webb, Claude A. Lieut., F. A., U. S. R., Am. Exp. Force, France.

Webb, De Witt Clinton. Civ. Engr., U. S. N. (rank of Lt.-Commander), Navy Yard, Philadelphia, Pa.

Webb, George H. Lt.-Col., 16th U. S. Engrs. (Ry.), Am. Exp. Force, France.

Webb, I. Gano. Capt., Engrs., U. S. R., Camp Lee, Petersburg, Va.

Webb, Walter Loring. Maj., Engrs., U. S. R., Am. Exp. Force, France.

Webster, Maurice A. Capt., Ord. Dept., N. A., Aberdeen Proving Ground, Aberdeen, Md.

Weeks, W. C. Maj., Engrs., N. A., 32d Engrs., Camp Grant, Rockford, Ill.

Welles, Theodore L., Jr. 2d Lieut., U. S. R., 318th Engrs., Vancouver Barracks, Wash.

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Wenige, Arthur E. Maj., U. S. R., 317th Engrs., Camp Sherman, Chillicothe, Ohio.

Wenzell, Andrew P. Capt., Co. F, 16th U. S. Engrs. (Ry.), Am. Exp. Force, France.

West, Edward Hazzard. Capt., U. S. R., Co. F, 5th Engrs., Corpus Christi, Tex.

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Whitman, Ezra B. Maj., Q. M. C., U. S. R.; Chf. Engr. of Utilities, Camp Meade, Admiral, Md.

Whitman, Ralph. Civ. Engr., U. S. N. (rank of Lt.-Commander); Aide on Staff of U. S. Military Governor of Santo Domingo, Santo Domingo, Dominican Republic.

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Whitney, Ralph Edward. 1st Lieut., San. Corps, N. A., San Insp.'s Office, Camp Lewis, American Lake, Wash.

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Wickersham, John H. Capt., Engrs., U. S. R., P. O. 706, Am. Exp. Force, France.

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Wildish, Frederic Newton. Capt., U. S. R., Co. B, 309th Engrs., N. A., Camp Zachary Taylor, Ky.

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Willard, N. R. Capt., Engrs., U. S. R., 510th Service Bn., Camp Lee, Petersburg, Va.

Williams, Alan F. Master Engr. (Junior Grade), Headquarters Co., 18th Engrs. (Ry.), U. S. Army P. O. No. 705, Am. Exp. Force, France.

Williams, Gardner S. Maj., Engrs., U. S. R. (*Unassigned*), Cornwell Bldg., Ann Arbor, Mich.

Williams, Samuel W. Maj., Engrs., U. S. R.; Asst. Engr., 90th Div., Camp Travis, Tex.

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Williar, Harry D., Jr. 1st Lieut., 1st U. S. Engrs., Am. Exp. Force, France.

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Wilson, Harry P. Capt., U. S. R., 310th Engrs., Camp Custer, Mich.

Wilson, Robert B. M. Capt., U. S. R., 311th Engrs., Camp Grant, Rockford, Ill.

Wilson, William R. Maj., 23d Field Co., R. E., B. E. F., France.

Wing, Charles B. Maj., 23d Engrs., Camp Meade, Admiral, Md.

Winn, Walter E. Lt.-Col., U. S. R., 114th Engrs., 39th Div., Camp Beauregard, Alexandria, La.

Winn, Walter S. Maj., Engrs., U. S. R., 4th and 1st National Bank Bldg., Nashville, Tenn.

Winton, Walter Ferrell. Capt., 14th U. S. Field Artillery, Fort Sill, Okla.

Wood, B. Russell. Capt., Engrs., U. S. R., Care Depot Engr.'s Office, Terminal Bldg., Hoboken, N. J.

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Woolworth, W. H. Capt., U. S. A., Headquarters, 2d Brigade, 1st Div., Am. Exp. Force, France.

Wooten, William P. Maj., Corps of Engrs., U. S. A., Brownsville, Tex.

Wright, John Bertram. Capt., U. S. R., 9th Co. Engrs., Camp Lee, Petersburg, Va.

Wrightson, William D. Maj.; Chf. of San. Corps, Surgeon-General's Office, War Dept., Washington, D. C.

Yereance, Alex. W. 1st Lieut., Co. F, 305th Pioneer Engrs., Camp Lee, Petersburg, Va.

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Young, George S. Capt., Engrs., U. S. R., Camp Lee, Petersburg, Va.

Young, Samuel M. Capt., Engrs., U. S. R.; 1422 Massachusetts Ave., N. W., Washington, D. C.

Zinn, George A. Col., Corps of Engrs., U. S. A., 321 Custom House, Portland, Ore.

MEMBERSHIP

(From March 8th to April 4th, 1918)

ADDITIONS

MEMBERS		Date of Membership.
ANDERS, FRANK LA FAYETTE. Cons. Engr.; City Engr., Fargo, N. Dak.	Assoc. M. M.	June 6, 1911 Mar. 12, 1918
ATKINSON, ASHER. City Engr. (Res., 49 Mine St.), New Brunswick, N. J.	Assoc. M. M.	April 5, 1905 Mar. 12, 1918
BEEBEE, RALPH AGUSTUS. Efficiency Engr., City of Oakland, City Hall, Oakland, Cal.	Jun. Assoc. M. M.	Sept. 1, 1908 April 2, 1912 Mar. 12, 1918
BEEKMAN, JOHN VAN DERVEER, JR. Pres., Whidden-Beekman Co., 70 Devonshire St., Boston, Mass.	Jun. Assoc. M. M.	Sept. 3, 1901 July 10, 1907 Mar. 12, 1918
CONGER, ALGER ADAMS. Hydr. Engr., Power Constr. Co., 35 Harvard St., Worcester, Mass.	Assoc. M. M.	Oct. 1, 1902 Mar. 12, 1918
DE VOU, JAMES LAIRD. Mgr., Central Div., Erecting Dept., Am. Bridge Co., 1525 Frick Bldg., Pittsburgh, Pa.	Assoc. M. M.	April 1, 1903 Mar. 12, 1918
DOMINGUEZ, RALPH. Div. Engr., Comm. of Roads and Bridges, Argentine Republic, 120 Lavalle, Buenos Aires, Argentine Republic		Jan. 14, 1918
FINNELL, WOOLSEY. Maj., U. S. R., 501st Engrs., Am. Exp. Forces, France		Nov. 27, 1917
GRIEST, MAURICE. With Eng. Dept., Public Service Comm., First Dist., 105 West 163d St., New York City		Mar. 12, 1918
HULBERT, EVERSON CLIFTON. Civ. Engr., Crescent Portland Cement Co., Wampum, Pa.		Mar. 12, 1918
LAWSON, LAWRENCE MILTON. Project Mgr., Rio Grande Project, U. S. Reclamation Service, 1215 Mills Bldg., El Paso, Tex.	Assoc. M. M.	Oct. 3, 1906 Mar. 12, 1918
LICHTNER, WILLIAM OTTO. Cons. Engr. (Thompson & Lichtner), 136 Federal St., Boston, Mass.	Jun. Assoc. M. M.	Aug. 31, 1909 Jan. 2, 1912 Mar. 12, 1918
MACGLASHAN, ALEXANDER. Maj., 104th Engrs., U. S. A., Camp McClellan, Anniston, Ala.		Mar. 12, 1918
MCDANEL, MAYNARD SARGENT. Div. Engr., Constr. Dept., A. C. L. R. R., Room 2, Byrd St. Station (Res., 709 Moss-Side Ave.), Richmond, Va.		Mar. 12, 1918
PERRING, HENRY GARFIELD. (J. E. Greiner & Co.), 1319 Fidelity Bldg., Baltimore, Md.	Assoc. M. M.	Nov. 6, 1907 Mar. 12, 1918
REDDING, JOSEPH HERBERT. Div. Engr., W. J. & S. R. R., and Camden Terminal Divs., 322 Cooper St., Camden, N. J.		Mar. 12, 1918

MEMBERS (*Continued*)

		Date of Membership.
Spaulding, Ralph Edgar. Care, Eng. Dept., Fred T. Ley & Co., Inc., Springfield, Mass. (Res., Suffield, Conn.)	Jun. Assoc. M. M.	May 31, 1910 April 1, 1914 Mar. 12, 1918
Tenney, Arthur Arnold. Purchasing Agt. and Asst. Supt., The Fitchburg Steam Engine Co., 102 Pleasant St., Fitchburg, Mass.		Mar. 12, 1918
Topping, Perry. Capt., U. S. R., 5th U. S. Engrs., Corpus Christi, Tex.	Assoc. M. M.	Feb. 6, 1912 Sept. 11, 1917
Travell, Warren Bertram. Chf. Engr., Butterworth-Judson Corporation, 337 West 14th St., New York City	Jun. Assoc. M. M.	April 30, 1895 Mar. 5, 1902 Jan. 14, 1918
Waters, William Lawrence. Cons. Engr., 50 Broad St., New York City		Mar. 12, 1918
Wheeler, Walter Austin. Chf. Engr., Blodgett Constr. Co., 325 Ry. Exchange, Kansas City, Mo.	Assoc. M. M.	May 31, 1916 Mar. 12, 1918

ASSOCIATE MEMBERS

Allison, Leonidas Metcalfe. The Chesterfield, Louisville, Ky.		Mar. 12, 1918
Bassett, William Manning. Asst. to Engr. of Structures, Elec. Zone, N. Y. C. R. R., 266 Park Hill Ave., Yonkers, N. Y.		Mar. 12, 1918
Borough, Edwin Wallace. Box 23, Trenton Falls, N. Y.		Jan. 14, 1918
Braun, Walter. Designing and Civ. Engr. (Braun, Fleming & Knollman), 233 South High St., Columbus, Ohio		Mar. 12, 1918
Campbell, Charles Cecil. Asst. Engr., George Mormann, 710 Heed Bldg. (Res., 870 North Ringgold St.), Philadelphia, Pa.	Jun. Assoc. M.	Dec. 31, 1913 Mar. 12, 1918
Clow, George Valentine. Const. Dept., The National Cash Register Co., Dayton, Ohio		Mar. 12, 1918
Cottingham, George, Jr. Roadmaster, N. P. Ry., Box 423, Carrington, N. Dak.		Nov. 27, 1917
Dodge, Clyde Raymond. Res. Engr., Broad St. Viaduct, Bronx Parkway Comm., 23 Midland Ave., Bronxville, N. Y.		Mar. 12, 1918
Gay, George Inness. Care, Comm. for Relief in Belgium, 3 London Wall Bldgs., London, E. C. 2, England	Jun. Assoc. M.	Sept. 3, 1912 Jan. 14, 1918
Geiger, Albert Francis. Chf. Engr., The Porcupine Co., 730 Wordin Ave., Bridgeport, Conn.		Mar. 12, 1918
Gooch, Carl Joseph. Co. E, 32d Engrs., Camp Grant, Rockford, Ill.		Mar. 12, 1918

ASSOCIATE MEMBERS (*Continued*)

		Date of Membership.
GUSTAFSON, EMIL NILES. Highway Engr., Matagorda County, Bay City, Tex		Mar. 12, 1918
HAMMOND, HARRY PARKER. Prof. of San. and Hydr. Eng., Polytechnic Inst. of Brooklyn, 99 Livingston St., Brooklyn, N. Y		Jan. 14, 1918
HART, BERT MARCELLUS. City Engr., 304 City Hall, Oklahoma, Okla		Mar. 12, 1918
HOPKINS, CECIL BLAINE. Pacific Coast Mgr., Concrete Eng. Co., Inc., 301 Rialto Bldg., San Francisco, Cal		Mar. 12, 1918
HORRIGAN, WILLIAM JAMES. Cons. and Const. Engr., with H. M. Wilkes Co., Beaufort, N. C	Jun. Assoc. M.	June 1, 1909 Mar. 12, 1918
LEAL, HENRY WAY. Pilot Engr., C., M. & St. P. Ry., 709 Lyon and Healy Bldg., Chicago, Ill		Oct. 9, 1917
LIDRAL, JOHN FRANK. 34 Downs Bldg., Seattle, Wash		Mar. 12, 1918
McINTYRE, LEWIS WEDSEL. Asst. Prof., Eng. School, Univ. of Pittsburgh, 309 North Fairmont St., Pittsburgh, Pa.		Mar. 12, 1918
MEREDITH, WYNN. Res. Engr., California Highway Comm., Fortuna, Cal		Mar. 12, 1918
MIXSELL, HARRY WORTHINGTON. Asst. Engr., Board of Public Utility Commrs., 163 Washington St., Phillipsburg, N. J		Mar. 12, 1918
MORRISON, GILBERT. 1724 Erie Ave., Williamsport, Pa		Nov. 27, 1917
MURRAY, FENWICK HALL. Acting State Highway Engr., 5th Floor, Union National Bank Bldg., Columbia, S. C		Mar. 12, 1918
MURRAY, JAMES LEE. Care, The Riordon Pulp & Paper Co., Ltd., Hawkesbury, Ont., Canada		Oct. 9, 1917
PARKE, SAMUEL REYNOLDS. Asst. Engr., State Dept. of Health, Camp Hill, Pa		Mar. 12, 1918
PAYNE, LOUIS WATTERS. 3605 Fourteenth St., N. W., Washington, D. C	Jun. Assoc. M.	Dec. 3, 1913 Jan. 14, 1918
POLHEMUS, JAMES HENRY. Gen. Mgr., Coos Bay Shipbuilding Co., Marshfield, Ore		Mar. 12, 1918
POOLE, RUBLE ISAAC. 1st Co., R. O. T. C., Military Branch, Chattanooga, Tenn	Jun. Assoc. M.	Dec. 6, 1910 Jan. 14, 1918
PUCKETT, HOMER. Hodgenville, Ky		Mar. 12, 1918
RAPP, PHILIP. Care, Truscon Steel Co., Youngstown, Ohio		Mar. 12, 1918
REYNOLDS, EDWIN GEORGE, JR. 22 President St., New Rochelle, N. Y		Mar. 12, 1918
ROWLAND, JAMES WALLACE. Asst. Engr., Dept. of Wharves, Docks and Ferries, 8127 Elberon Ave., Fox Chase, Philadelphia, Pa		Mar. 12, 1918

ASSOCIATE MEMBERS (*Continued*)		Date of Membership.
SCHWARTZ, LLOYD. First Asst., Dist. No. 1, Illinois Dept. of Public Works and Bldgs., Div. of Highways, 138 Fox St., Aurora, Ill.		Mar. 12, 1918
SEYBOLT, GEORGE HUDSON. Supt., Tower Fabricating Shop and Galvanizing Plant, Milliken Bros. (Inc.), 110 Springfield Ave., West New Brighton, N. Y.		Mar. 12, 1918
STABELL, FREDERICK PHILIP. Care, Engr., M. of W., The Connecticut Co., New Haven, Conn.		Mar. 12, 1918
STANTON, WILLIAM FRANK. Chf. Asst., Valparaiso Port, Casilla 1004, Valparaiso, Chile		Jan. 14, 1918
STILLWELL, HOWARD LOGAN. Care, South Eastern Underwriters Assoc., Box 1743, Atlanta, Ga.		Mar. 12, 1918
SVANÖE, HAAKON HOLDT. 446 Thirty-sixth St., North Milwaukee, Wis.		Mar. 12, 1918
THOMPSON, CARROLL ROSE. First Asst. to Harbor Engr., Dept. of Wharves, Docks and Ferries, 618 Leverington Ave., Roxboro, Philadelphia, Pa.		Mar. 12, 1918
URQUHART, LEONARD CHURCH. Instr., Bridge Eng., Coll. of Civ. Eng., Cornell Univ., 127 Eddy St., Ithaca, N. Y.		Mar. 12, 1918
WEED, LLOYD WOOLSEY. Care, Liberty Shipbuilding Co., Brunswick, Ga.	Jun. Assoc. M.	Sept. 12, 1916 Mar. 12, 1918
WELTY, PERRY ALLEN. Engr. and Supt., Cameron County Water Impvt. Dist. No. 2, San Benito, Tex.		Mar. 12, 1918
WERNECKE, CHAUNCY. Instr. in Civ. Eng., Univ. of Washington, 4546 Eighteenth Ave., N. E., Seattle, Wash.	Jun. Assoc. M.	Mar. 4, 1913 Mar. 12, 1918
WILLIS, MERTON HORATIO. Destrehan, La.		Jan. 14, 1918

JUNIORS

CHILD, JOHN TOWNSHEND. 501 Arlington Bldg., Rochester, N. Y.	Mar. 12, 1918
GODFREY, ALEXANDER HOLLIS. Cynwyd, Pa.	Mar. 12, 1918
JENKINS, THOMAS VINNEDGE. 902 Southwestern Life Bldg., Dallas, Tex.	Mar. 12, 1918
LAVERTY, SAMUEL PERRY. Reg. Sup. Sergeant, 316th Am. Tr., Co. 5, E. R. O. T. C., Camp Lee, Petersburg, Va.	Nov. 27, 1917
LO, YING. P. O. Box 87, Grand Central Station, New York City	Mar. 12, 1918
PERKINS, ROSCOE, JR. Cornwells Heights, Pa.	Mar. 12, 1918
STAGER, FREDERICK FRANK. Structural Draftsman, McClintic-Marshall Co., 410 Anthony St., Carnegie, Pa.	Mar. 12, 1918

CHANGES OF ADDRESS

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AIMS, WALTON IRVING. 150 Nassau St., New York City.

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Allen, James Pierson. Asst. Engr., U. S. Engr. Office (Res., 8 Ladson St.), Charleston, S. C.

Arend, Albert Cornelius. Cons. Engr., 929 City National Bank Bldg., Omaha, Nebr.

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Brodie, Orrin Lawrence. Care, Air Nitrates Corporation, Muscle Shoals, Ala.

Burgess, Harry. Col. Engrs., N. A., 16th Engrs. (Ry.), Am. Exp. Forces, France.

Burrage, John Otis. Engr., Div. of Shipyard Plants, Emergency Fleet Corporation, Washington, D. C.

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Cowles, William Pierce. Maj., Engrs. U. S. R., E. R. O. T. C., Camp Lee, Va.; 3227 Portland Ave., Minneapolis, Minn.

Crecelius, Samuel Forder. Maj., U. S. R., 101st Engrs., Am. Exp. Forces, France.

MEMBERS (*Continued*)

CROSBY, WALTER WILSON. Lt.-Col., Engrs., N. A., 104th Engrs., Camp McClellan, Anniston, Ala.

CUNNINGHAM, JOHN GEORGE LAWRENCE. Capt., Ord., U. S. R.; A. Q. M., U. S. A., Constr. Div., 7th and B Sts., Washington, D. C.

DEAN, BERTRAM DODD. Capt., U. S. R., Co. B, 25th Engrs., and Regimental Adjt., Am. Exp. Forces, France.

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ELLIOTT, JAMES WILLIAM. Capt., Engrs., U. S. R., E. R. O. T. C., Camp Lee, Petersburg, Va.

FOX, HENRY. Capt., U. S. R., 314th Engrs., Camp Funston, Kans.

FOX, STEPHENSON WATERS. Maj., Engrs. U. S. R., 601 G St., N. W., Washington, D. C.

FREDERICKSON, JOHN HENRY. Care, James Stewart & Co., Inc., U. S. M. P. O. 705, Am. Exp. Forces, France.

FRENCH, CARSON GEYER. Cons. Structural Engr., 210 Electric Bldg., Cleveland, Ohio.

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GARTENSTEIG, CHARLES. Capt., Engrs. U. S. R., Camp Lee, Va. (Res.. 35 West 96th St., New York City).

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GIRAND, JAMES BELL. Cons. Engr., 201 National Bank Bldg., Phœnix, Ariz.

GOETHALS, GEORGE WASHINGTON. Maj.-Gen., U. S. A. (*Retired*); Cons. Engr., 40 Wall St., New York City.

GRAVES, EDWARD MICHAEL. Maj., U. S. R., 28th Engrs., Camp Meade, Md.; 1105 Swetland Bldg., Cleveland, Ohio.

HANSEN, ANDREW CHRISTIAN. City Engr., 240 South Broadway, Room 402, Los Angeles, Cal.

HARVEY, HERBRAND. Res. Engr., Chile Exploration Co., Chuquicamata (*via* Antofagasta), Chile.

HAYDEN, JOHN BRUCE. Pleasant Ridge, Ohio.

HOLLYDAY, RICHARD CARMICHAEL. Civ. Engr., U. S. N. (rank of Capt.), Navy Yard, Norfolk, Va.

HORNE, HAROLD WELLINGTON. Care, The Miami Conservancy Dist., Dayton, Ohio.

HUDSON, CLARENCE WALTER. Prof. of Civ. Eng., Polytechnic Inst. of Brooklyn; Cons. Engr., 15 Park Row, New York City.

JACOBS, JOSEPH. Maj., U. S. R., 509th Engrs. (Service Bn.), Am. Exp. Forces, France.

JUENGST, HENRY FREDERICK. Care, Kokomo Water-Works Co., Kokomo, Ind.

MEMBERS (*Continued*)

KETCHUM, MILO SMITH. (*Director.*) Dean, Coll. of Eng., and Prof. of Civ. Eng., Univ. of Colorado, Boulder, Colo.; Asst. Director in Chg. of Constr., U. S. Government Explosives Plant C, Nitro, W. Va.

LACKEY, OSCAR FRANCIS. Care, Louis L. Brown & Co., 30 Church St., New York City.

LANGTHORN, JACOB STINMAN. Cons. Engr., Beaver Eng. & Contr. Co. Filtration Plant, Accotink, Va.

LINDBERY, CHARLES ARTHUR. Capt., U. S. R., 601st Engrs., Camp Laurel, Md.

MONCRIEFF, JOHN MITCHELL. Lt.-Col., R. E., Union Club, Newcastle-on-Tyne, England.

MOORE, JAMES EDWIN ALEXANDER. Civ. and Mech. Engr., 1900 Euclid Bldg., Room 703, Cleveland, Ohio.

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Logan, Vernon Lemley. 1st Class Sergeant, Co. A, 110th Engrs.; Co. 5, E. R. O. T. C., Camp Lee, Petersburg, Va.

McIntyre, William John. 17 Lakeside Pl., Morristown, N. J.

Morse, Frederick Thurlough. Office Engr., A. T. & S. F. Ry., Passenger Depot, Topeka, Kans.

Ohrt, Frederick. San. Engr., Board of Health, Honolulu, Hawaii.

Owen, Bartram Ashmead. Bridge Insp., P. R. R., Room 360, Broad St. Station (Res., 5807 Hazel Ave.), Philadelphia, Pa.

Peck, John Sanford. Private, U. S. Army School, Military Aeronautics, Photo Div., Ithaca, N. Y.

Praeger, Emil. Asst. Engr., U. S. N. (rank of Lieut. (Junior Grade)), 2346 Union St., San Diego, Cal.

Rhynus, Clarence Paulding. Asst. San. Engr., U. S. Public Health Service, U. S. Hygienic Laboratory, Washington, D. C.

Richards, George William. 1530 Frick Bldg., Pittsburgh, Pa.

Robinson, William Ernest. Lieut., U. S. R., Co. E, 1st Engrs., U. S. A., Am. Exp. Forces, France.

Ruettgers, Arthur. Junior Engr., U. S. Reclamation Service, 1524 Pearl St., Denver, Colo.

Searight, George Peter. 1st Lieut., U. S. R., 302d Engrs., Camp Upton, N. Y. (Res., 3 East Louther St., Carlisle, Pa.).

Sell, William Osborne. Structural Engr. (W. G. Kirkpatrick), Box 222, Charleston, W. Va.

Sleight, Reuben Benjamin. Lieut., Sig. C., U. S. A.; Care, L. J. Sleight, Laingsburg, Mich.

Smith, Herschel C. Asst. Engr., State Highway Dept., Oklahoma, Okla.

JUNIORS (*Continued*)

STAFFORD, HARLOWE MCVICKER. Box 473, Willows, Cal.

STANLEY, WILLIAM EDWARD. 1st Lieut., U. S. R., Co. B, 101st Engrs., Am. Exp. Forces, France; Care, J. W. Stanley, Burrton, Kans.

STEM, CLIFFORD HOEY. 2d Lieut., U. S. R., 101st Engrs., L. of C., Am. Exp. Forces, France.

TINGLEY, FRANCIS. Engr., Altoona & Logan Val. Elec. Ry., Altoona, Pa.

VELTFORT, THEODORE ERNST. Progress Engr., Am. International Shipbuilding Corporation, 140 North Broad St., Philadelphia (Res., H.14 Third Ave., Presser Park, Yeadon), Pa.

WALKER, ROBERT YULE. Contr. (Taylor & Walker), 601 Majestic Bldg., Oklahoma, Okla.

WHEELER, FRANK IGNATIUS, JR. 2d Lieut., A. S., Sig. R. C., Equipment Div., Insp. Dept., Sig. C., 119 D St., N. E., Washington, D. C.

WILLCOX, HENRY. 1565 Fifteenth St., Augusta, Ga.

WILLIAMS, ALAN FRANK. Master Engr. (Junior Grade), Headquarters Co., 18th Engrs. (Ry.), U. S. Army P. O. No. 705, Am. Exp. Forces, France.

YERKANCE, ALEXANDER WOODWARD. 1st Lieut., Co. F, 305th Pioneer Engrs., Camp Lee, Petersburg, Va.

DEATHS

ASPINWALL, THOMAS. Elected Member, May 2d, 1888; died March 2d, 1918.

BROWN, CHARLES OTTO. Elected Junior, January 6th, 1875; Member, November 7th, 1877; died March 10th, 1918.

HOWARD, OLIVER ZELL. Elected Associate Member, February 28th, 1911; Member, May 15th, 1917; died December 20th, 1917.

OPDYKE, STACY BROWN, JR. Elected Member, February 2d, 1876; died October 24th, 1917.

SMITH, PLUMER HENRY. Elected Associate Member, January 7th, 1913; died January 18th, 1918.

STEVENS, EDWIN AUGUSTUS. Elected Member, June 3d, 1915; died March 8th, 1918.

VAN BUREN, JOHN D. Elected Member, May 20th, 1868; died March 11th, 1918.

WILCOX, FRED ELMER. Elected Associate Member, April 1st, 1896; died March 21st, 1918.

Total Membership of the Society, April 4th, 1918, 8 672.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(March 1st to 31st, 1918)

NOTE.—*This list is published for the purpose of placing before the members of this Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(2) *Journal,* Engrs. Club of Phila., Philadelphia, Pa.
(3) *Journal,* Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal,* Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Transactions,* Can. Soc. C. E., Montreal, Que., Canada.
(6) *Journal,* Am. Inst. of Archts., Washington, D. C., 50c.
(7) *Gesundheits Ingenieur,* München, Germany.
(8) *Stevens Indicator,* Hoboken, N. J., 50c.
(9) *Industrial Management,* New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, 432 Fourth Ave., New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News-Record,* New York City, 15c.
(15) *Railway Age,* New York City, 15c.
(16) *Engineering and Mining Journal,* New York City, 15c.
(17) *Electric Railway Journal,* New York City, 10c.
(18) *Railway Review,* Chicago, Ill., 15c.
(19) *Scientific American Supplement,* New York City, 10c.
(20) *Iron Age,* New York City, 20c.
(21) *Railway Engineer,* London, England, 1s. 2d.
(22) *Iron and Coal Trades Review,* London, England, 6d.
(23) *Railway Gazette,* London, England, 6d.
(24) *American Gas Engineering Journal,* New York City, 10c.
(25) *Railway Mechanical Engineer,* New York City, 20c.
(26) *Electrical Review,* London, England, 4d.
(27) *Electrical World,* New York City, 10c.
(28) *Journal,* New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal,* Royal Society of Arts, London, England, 6d.
(30) *Annales des Travaux Publics de Belgique,* Brussels, Belgium, 4 fr.
(31) *Annales* de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand, Brussels, Belgium, 4 fr.
(32) *Mémoires et Compte Rendu des Travaux,* Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil,* Paris, France, 1 fr.
(34) *Portefeuille Economiques des Machines,* Paris, France.
(35) *Nouvelles Annales de la Construction,* Paris, France.
(36) *Cornell Civil Engineer,* Ithaca, N. Y.
(37) *Revue de Mécanique,* Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways,* Paris, France.
(39) *Technisches Gemeindeblatt,* Berlin, Germany, 0, 70m.
(40) *Zentralblatt der Bauverwaltung,* Berlin, Germany, 60 pfg.
(41) *Electrötechnische Zeitschrift,* Berlin, Germany.
(42) *Proceedings,* Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées,* Paris, France.
(44) *Journal,* Military Service Institution, Governors Island, New York Harbor, 50c.
(45) *Coal Age,* New York City, 10c.
(46) *Scientific American,* New York City, 15c.
(47) *Mechanical Engineer,* Manchester, England, 3d.
(48) *Zeitschrift,* Verein Deutscher Ingenieure, Berlin, Germany, 1, 60m.
(49) *Zeitschrift für Bauwesen,* Berlin, Germany.
(50) *Stahl und Eisen,* Düsseldorf, Germany.
(51) *Deutsche Bauzeitung,* Berlin, Germany.
(52) *Rigasche Industrie-Zeitung,* Riga, Russia, 25 kop.
(53) *Zeitschrift,* Oesterreichischer Ingenieur und Architekten Vereines, Vienna, Austria, 70h.
(54) *Transactions,* Am. Soc. C. E., New York City, $12.
(55) *Transactions,* Am. Soc. M. E., New York City, $10.

(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $6.

(57) *Colliery Guardian*, London, England, 5d.

(58) *Proceedings*, Engrs.' Soc. W. Pa., 2511 Oliver Bldg., Pittsburgh, Pa., 50c.

(59) *Proceedings*, American Water-Works Assoc., Troy, N. Y.

(60) *Municipal Engineering*, Indianapolis, Ind., 25c.

(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.

(62) *American Drop Forger*, Thaw Bldg., Pittsburgh, Pa., 10c.

(63) *Minutes of Proceedings*, Inst. C. E., London, England.

(64) *Power*, New York City, 5c.

(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.

(66) *Gas Journal*, London, England, 6d.

(67) *Cement and Engineering News*, Chicago, Ill., 25c.

(69) *Der Eisenbau*, Leipzig, Germany.

(71) *Journal*, Iron and Steel Inst., London, England.

(71*a*) *Carnegie Scholarship Memoirs*, Iron and Steel Inst., London, England.

(72) *American Machinist*, New York City, 15c.

(73) *Electrician*, London, England, 18c.

(74) *Transactions*, Inst. of Min. and Metal., London, England.

(75) *Proceedings*, Inst. of Mech. Engrs., London, England.

(77) *Journal*, Inst. Elec. Engrs., London, England, 5s.

(78) *Beton und Eisen*, Vienna, Austria, 1, 50m.

(79) *Forscherarbeiten*, Vienna, Austria.

(80) *Tonindustrie Zeitung*, Berlin, Germany.

(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.

(83) *Gas Age*, New York City, 15c.

(84) *Le Ciment*, Paris, France.

(85) *Proceedings*, Am. Ry. Eng. Assoc., Chicago, Ill.

(86) *Engineering and Contracting*, Chicago, Ill., 10c.

(87) *Railway Maintenance Engineer*, Chicago, Ill., 10c.

(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.

(89) *Proceedings*, Am. Soc. for Testing Materials, Philadelphia, Pa., $5.

(90) *Transactions*, Inst. of Naval Archts., London, England.

(91) *Transactions*, Soc. Naval Archts. and Marine Engrs., New York City.

(92) *Bulletin*, Soc. d'Encouragement pour l'Industrie Nationale, Paris, France.

(93) *Revue de Métallurgie*, Paris, France, 4 fr. 50.

(95) *International Marine Engineering*, New York City, 20c.

(96) *Canadian Engineer*, Toronto, Ont., Canada, 10c.

(98) *Journal*, Engrs. Soc. Pa., Harrisburg, Pa., 30c.

(99) *Proceedings*, Am. Soc. of Municipal Improvements, New York City, $2.

(100) *Professional Memoirs*, Corps of Engrs., U. S. A., Washington, D. C., 50c.

(101) *Metal Worker*, New York City, 10c.

(102) *Organ für die Fortschritte des Eisenbahnwesens*, Wiesbaden, Germany.

(103) *Mining and Scientific Press*, San Francisco, Cal., 10c.

(104) *The Surveyor and Municipal and County Engineer*, London, England, 6d.

(105) *Metallurgical and Chemical Engineering*, New York City, 25c.

(106) *Transactions*, Inst. of Min. Engrs., London, England, 6s.

(107) *Schweizerische Bauzeitung*, Zürich, Switzerland.

(108) *Southern Machinery*, Atlanta, Ga., 10c.

(109) *Journal*, Boston Soc. C. E., Boston, Mass., 50c.

(110) *Journal*, Am. Concrete Inst., Philadelphia, Pa., 50c.

(111) *Journal of Electricity, Power and Gas*, San Francisco, Cal., 25c.

(112) *Internationale Zeitschrift für Wasser-Versorgung*, Leipzig, Germany.

(113) *Proceedings*, Am. Wood Preservers' Assoc., Baltimore, Md.

(114) *Journal*, Institution of Municipal and County Engineers, London, England, 1s. 6d.

(115) *Journal*, Engrs.' Club of St. Louis, St. Louis, Mo., 35c.

(116) *Blast Furnace and Steel Plant*, Pittsburgh, Pa., 15c.

(117) *Engineering and Cement World*, Chicago, Ill.

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How to Proportion Unsymmetrical Concrete Arches.* Joseph P. Schwada. (13) Feb. 28.

High-Line Viaduct and Bridge Improve Rail Entrance to Kansas City.* F. W. Epps. (13) Feb. 28.

The Chouteau Avenue Viaduct.* (67) Mar.

Through-Arch Bridges of Reinforced Concrete.* Albert M. Wolf. (117) Mar. 1.

Double-Deck Railway Bridge Over Kansas River with Thin Floor Construction.* F. W. Epps. (13) Mar. 7.

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Erection of Kettle Rapids Bridge.* Sterling Johnston. (96) Mar. 7.
Precast Bridge Slabs of Concrete Incased I-Beams.* (13) Mar. 14.
New Details for Draw Span Bearings.* (15) Mar. 15.
Unusual Failure of a Railroad Draw Bridge.* (15) Mar. 15.
Einfaches Verfahren zur Bestimmung der Axe der Brückengewölbe.* A. Strassner. (107) Feb. 9.
Ergebnisse der Untersuchung von Eisenbetonbrücken der Schweiz. Bundesbahnen.* A. Bühler. (107) Feb. 23.

Electrical.

Testing Electric Ignition Apparatus.* J. D. Morgan. (11) Feb. 8.
The Storage Battery. (45) Feb. 16.
New 52 000-kw. Station of New Bedford Company.* (27) Serial beginning Feb. 23.
The Forces Which Act Upon a Transmission Line.* Charles R. Harte. (17) Feb. 23.
Applications of Flywheels in Motor Operation.* C. E. Clewell. (27) Feb. 23.
Factors Affecting Vapor-Rectifier Performance.* William Tschudy. (27) Feb. 23.
Some Considerations in Determining the Capacity of Rolling-Mill Motors.* Robert F. Hamilton. (42) Mar.
Selection of Steel Mill Auxiliary Motors and Control as Affected by Mechanical Features of the Drives.* J. D. Wright. (42) Mar.
Steel Mill Lighting and War Economy.* Samuel G. Hibbin. (116) Mar.
The Electric Lighting of Ecclesiastical Buildings.* William Wilson. (77) Mar.
Design of Underground Distribution for Electric Light and Power Systems.* G. J. Newton. (42) Mar.
Ultraviolet Energy and Its Use. M. Luckiesh. (105) Mar. 1.
Temperature Effects in Direct-Current Meters. G. W. Stubbings. (26) Mar. 1.
Problems in Atomic Structure.* J. J. Thomson. (Abstract of a paper.) (11) Mar. 1.
The Lighting of a Museum.* Clothilde Grunsky. (111) Mar. 1.
Ground Connections for Distribution Systems. W. C. Heston. (111) Mar. 1.
Innovations in Theatre Illuminating.* (111) Mar. 1.
Initial Current Obtained in Incandescent Lamps.* C. J. Berry. (27) Mar. 2.
Adapting Induction Meters to New Frequency.* E. L. Fischer. (27) Mar. 2.
Selection of Motors Aided by Graphic Meters.* C. E. Clewell. (27) Mar. 2.
The Development by X-Rays of Two New Fields.* L. E. Dodd. (19) Serial beginning Mar. 2.
New Power Source for Columbus (Ohio) Railways.* (17) Mar. 2.
Interconnection of Plants in Massachusetts.* (27) Mar. 2.
Columbus Company's Idea of a Modern Station.* (27) Mar. 2.
Substitutes in the German Electrical Industry. (11) Mar. 8.
Methods of Directing and Concentrating Light.* Haydn T. Harrison. (Abstract of paper read before the Illuminating Eng. Soc.) (26) Mar. 8.
Utilization of Second-Hand Line Materials.* L. M. Klauber. (27) Mar. 9.
Selection of Motors for Shipbuilding Plant.* David Elwell. (27) Mar. 9.
Flexible and Accurate Methods for Dielectric Tests.* Chester Arthur Butman. (27) Mar. 9.
Ninety-Five Thousand Kilowatt Addition to Northwest Station.* (64) Mar. 12.
Physical Data of the Highest Voltage System. H. A. Barre. (111) Mar. 15.
Recent Advances in Transmission Construction.* L. M. Klauber. (111) Mar. 15.
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Simple Method of Measuring Emfs. Accurately.* F. Wenner, Paul D. Foote and E. E. Weibel. (27) Mar. 16.
Increasing Transformer Capacity by Circulating Oil.* Claude H. Sheperd. (27) Mar. 16.
Getting the Most Out of Turbo-Generators.* L. H. Parker and J. J. Preble. (27) Mar. 16.
Doing Away with the Arc.* R. P. Burrows and J. T. Caldwell. (46) Mar. 16.
Maintenance of Electric Elevators. Charles W. Naylor. (64) Mar. 19.
Warrior Steam Plant of the Alabama Power Company.* W. B. West. (64) Mar. 19.
High Voltage Transmission Line Has Mile Span.* Romeo Morrissette. (96) Mar. 21.
What Synchronous Motors Can and Cannot Do.* Will Brown. (27) Mar. 23.
Increasing Carrying Capacity of Underground Cable.* E. O. Schweitzer. (27) Mar. 23.

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Offensive Against the Submarine. Joseph A. Steinmetz. (Abstract of paper read before Philadelphia Section of Am. Soc. of Mech. Engrs.) (55) Mar.
Selection of Motors for Shipbuilding Plant.* David Elwell. (27) Mar. 9.
The Problem of the Unsinkable Ship.* (46) Mar. 9.
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La constructions des navires de commerce aux Etats-Unis.* (33) Feb. 9.
Les convois des navires de commerce et leur protection contre les sous-marins. A. Poidlouë (33) Feb. 23.
L'Installation frigorifique du navire italien Resurrezione.* Ch. Dantin. (33) Mar. 2.
Der Kraftbedarf der Schiffstraktion und der Bahntraktion im Wettbewerb.* W. Kummer. (107) Feb. 16.

Mechanical.

Radiant Heat and Its Possibilities. Fred Champion. (Abstract of paper read before Pacific Coast Gas Assoc.) (83) Jan. 1.
Massachusetts Report on Calorific Standard. Charles D. Jenkins. (83) Feb. 1.
Use of Gas in Automobile Traction.* (From *Journal des Usines a Gaz.*) (83) Feb. 1.
Napthalene. W. Fletcher. (Paper read before the Manchester and District Junior Gas Assoc.) (66) Feb. 5.
Unusually Large Production of Water Gas in Continuous Vertical Retorts at Pernambuco, Brazil. Henry M. Balsam. (66) Feb. 5.
Dissolved Acetylene and Its Storage. (12) Feb. 8.
Pitch Measuring Machine for Screw Gauges.* (12) Feb. 8.
Building a Home-Made Crude Benzol Recovery Plant. C. F. W. Rendle. (Paper read before the Midland Junior Gas Assoc.) (83) Feb. 15.
Bonus Plan Reduces Coal Consumption at Manila. B. H. Blaisdell. (17) Feb. 16.
The Fuels and Waterpowers of Canada, a Consideration of Their Proper Spheres of Usefulness. A. S. L. Barnes. (96) Feb. 21.
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Modern Rectangular Coke-Oven Plant.* Dever C. Ashmead. (45) Feb. 23.
Developments in By-Product Coking. G. B. Walker. (Abstract of paper read before the Inst. of Civil Engrs.) (45) Feb. 23.
Problems of Crankshaft Design.* Otto M. Burkhardt. (Abstract of paper read before the Eng. Soc. of Buffalo, Automotive Section.) (55) Mar.
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The Vulcanization of Rubber. Andrew H. King. (105) Mar. 1.
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Human Element Too Important to Be Ignored with Continuous Vertical Retorts. Robert E. Wynant. (Paper read before New England Assoc. of Gas Engrs.) (24) Mar. 2.
The Technical History of the Airplane. F. M. Green. (Abstract of lecture given before the Aeronautical Soc. of Great Britain.) (19) Mar. 2.
Effect the Removal of Light Oils from Gas Has Upon Its Quality. L. J. Willien. (Abstract of paper published in *American Gas Institute News.*) (66) Mar. 5.
Faults of Ordinary Dry Meters. A. H. Whitelaw. (Extracts from paper read before Scottish Junior Gas Assoc.) (66) Mar. 5.
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Notes on General Gaging and the Manufacture of Gages.* H. James. (72) Mar. 14.
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A Plant to Transfer Coal and Ore Mechanically.* (15) Mar. 15.
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Watch Your Radiation Losses to Help Save Coal.* Austin Bolam. (27) Mar. 16.
Wreck of a Thirty-Five Thousand Kilowatt Turbine.* (64) Mar. 19.
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A Crank Case Trunnion Jig.* (72) Mar. 21.
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Development of the Pneumatic Sand-Blast.* Glenn B. Harris. (72) Mar. 21.
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Scrap Metal Baling Press.* (11) Feb. 1.
Gas Furnaces as Re-Heaters of Iron Piles, etc. Geo. Carrington. (Abstract of paper read before the Staffordshire Iron and Steel Inst.) (22) Feb. 8.
The British Spelter Industry.* (11) Serial beginning Feb. 15.
Blacksmithing at Coal Mines.* J. F. Springer. (45) Feb. 16.
Flotation of Chalcopyrite in Chalcopyrite Pyrrhotite Ores of Southern Oregon. Will H. Coghill. (16) Feb. 23.
Sulphur and Copper Oxide Determination. C. G. Maier. (16) Feb. 23.
Amalgamation and Roasting Practice in Gold Coast Colony. Paul T. Bruhl. (16) Feb. 23.
A Volume Regulator for Blast-Furnace Engines.* L. C. Loewenstein. (Abstract of paper read before the Am. Soc. of Mech. Engrs.) (55) Mar.
Potash Recovery from Blast Furnace Dust. R. A. Berry and D. N. McArthur. (Paper read before the Soc. of Chemical Industry.) (116) Mar.
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Application of Heat in Steel Treating. A. F. MacFarland. (Abstract of paper read before Chicago Section of the Steel Treating Research Soc.) (20) Mar. 7.
Making Cast Ammunition in France. E. Ronceray. (20) Mar. 7.
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Processes for the Manufacture of Aluminium.* (26) Serial beginning Mar. 8.
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Determination of Non-Sulphide Copper.* Charles E. van Barneveld and Edmund S. Leaver. (Abstract of *Technical Paper 198,* U. S. Bureau of Mines.) (103) Mar. 9.
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APRIL, 1918

Vol. XLIV. APRIL, 1918. No. 4.

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INSTITUTED 1852

PAPERS AND DISCUSSIONS

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AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

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CONSTRUCTION METHODS USED IN BUILDING THE LOWER RESERVOIR DAM OF THE BALMORHEA PROJECT.

By Vernon L. Sullivan, M. Am. Soc. C. E.

To be Presented May 15th, 1918.

Synopsis.

The object in writing this paper is to present economical and practical methods of constructing earth dams. In many cases, where the foundations are poor and a long section is to be built, these methods may suggest a solution which will enable the construction of a dam which, otherwise, would be impracticable or expensive.

The Balmorhea Project formerly consisted of a diversion canal which distributed the water of some very large springs for irrigation purposes. As the supply was insufficient for the area desired to be irrigated, there was constructed a reinforced concrete diversion dam, 500 ft. long, across a large and wide canyon; an intake canal, 4½ miles long, with a carrying capacity of 1 000 cu. ft. per sec.; a large earth dam, 3 900 ft. long, with a maximum height of 47 ft. above the lowest point in the creek bed, and having reinforced concrete paving on the

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Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

inner slope; an outlet conduit, well, and controlling gates; and an outlet canal, 2½ miles long.

Most of the excavation for the dam was done with a drag-line dredge, and the earth embankment was put in with twenty-six dump-wagons loaded by two elevators. The principal features of interest in this work were the excavation for the cut-off or puddle trench under the dam, the methods of settling and compacting the earth embankment, and the manner of providing a more or less flexible and expansible concrete pavement on the inner slope.

A small supply ditch, about 3 miles long, was first constructed, up the creek from a point on the hill at the height of the top of the proposed dam, in order to divert and provide water for construction purposes, principally for puddling the clay cut-off or core-wall, irrigating the earth lifts, and for concrete.

The cut-off trench, along the axis of the dam, was excavated through a rocky and gravelly surface and down to the rock or clay sub-surface, running from 0 to 20 ft. deep and from 10 to 40 ft. wide. This work (Fig. 1) was practically all done with a drag-line excavator, the excavated material of the better kind being used in the lower section of the dam.

As soon as sufficient excavation had been completed, a clay dam was placed across the trench, and the latter was filled with water from the supply ditch. Then selected clay was bull-dozed into the water-filled trench, as illustrated by Fig. 2. The filling of this trench through the water—shoving it in from the end all the time—made a complete puddle of the clay without any additional mixing.

The remaining portion of the natural surface under the proposed dam was cleared and thoroughly plowed, and then the earth embankment was put in, in lifts 3 or 4 ft. thick. Each lift was then irrigated thoroughly, as illustrated by Figs. 3 and 4, by bordering, checking, and flooding with water. The water put on each lift was sufficient to cause the moisture to unite thoroughly with the moisture of the previous lift, tests being made with post-hole diggers before the next lift was put on, and, when necessary, a second flooding was made, the object being to obtain a complete and uniform settlement of the earth, in the most economical and practical manner possible. As this method of actually saturating the earth with water quickly effects a most complete settle-

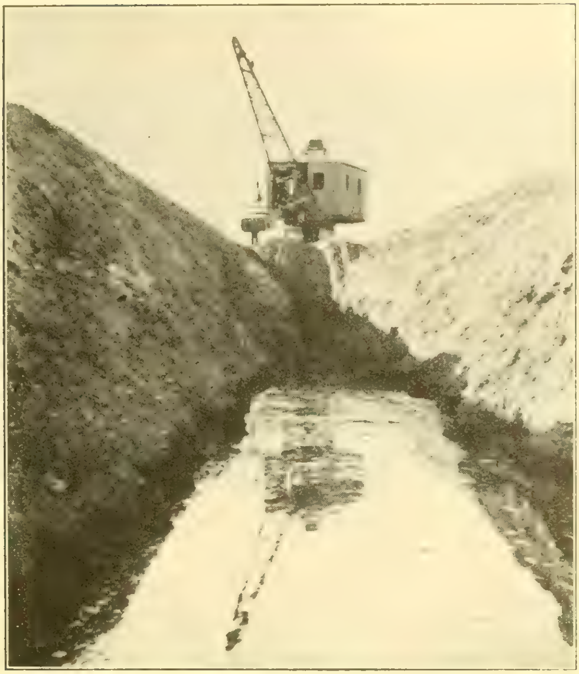

FIG. 1.—EXCAVATING PUDDLE TRENCH.

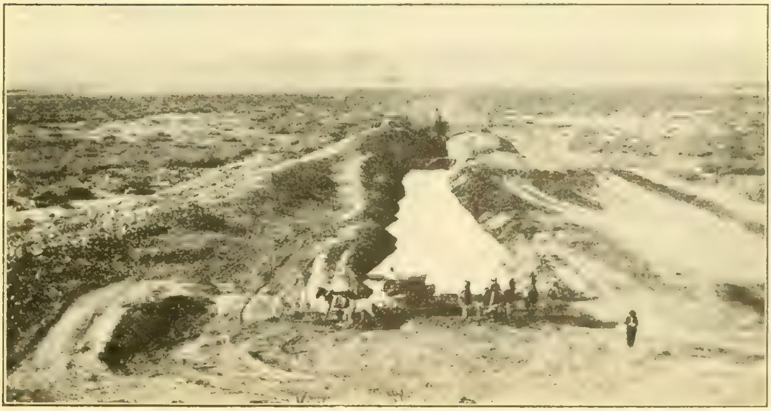

FIG. 2.—PUDDLING TRENCH.

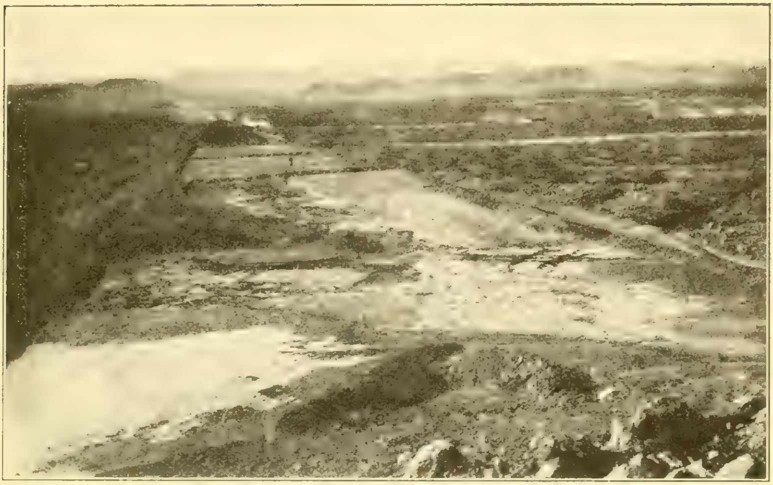

FIG. 3.—BALMORHEA DAM, DURING CONSTRUCTION.

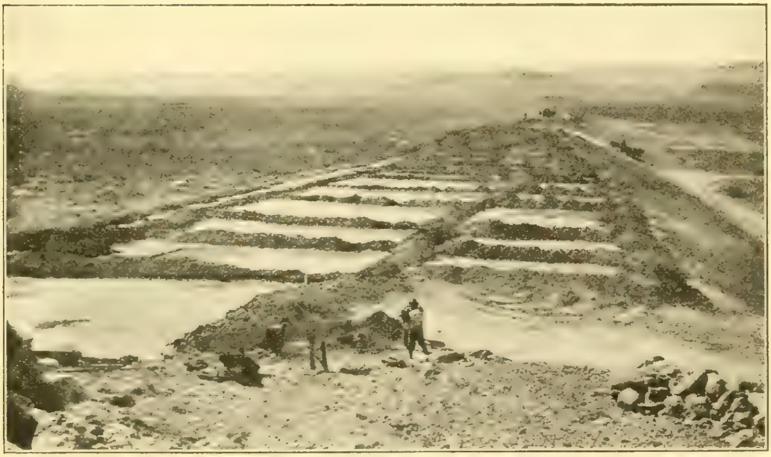

FIG. 4.—IRRIGATING EACH LIFT OF DAM.

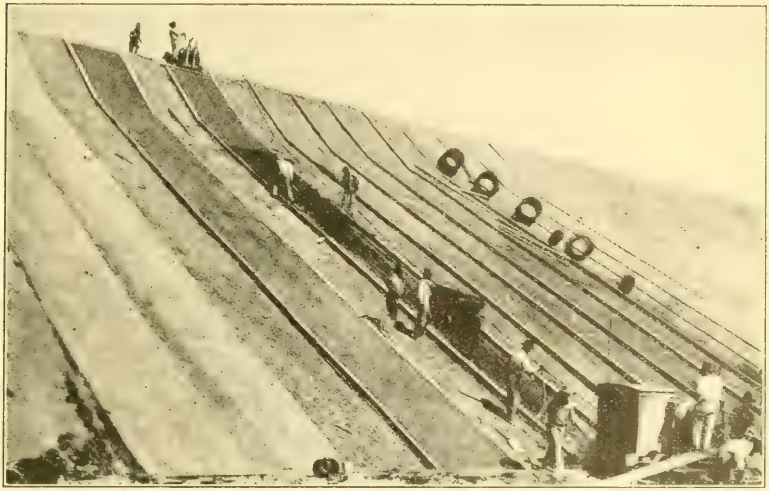

FIG. 5.—PAVING BALMORHEA DAM WITH REINFORCED CONCRETE.

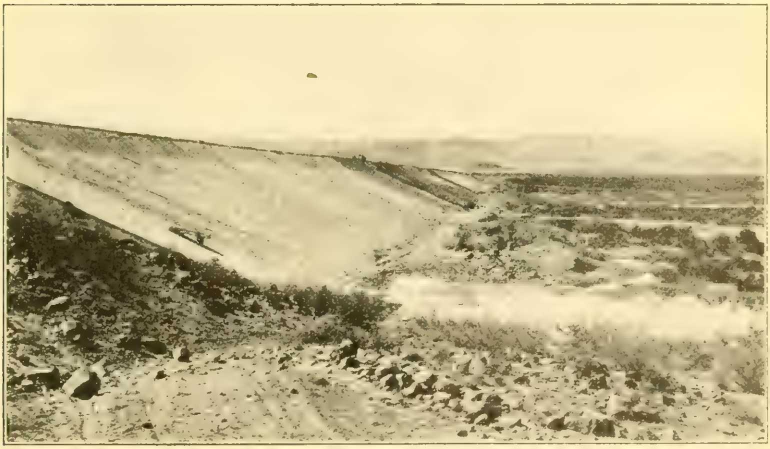

FIG. 6.—MAIN STORAGE DAM, BALMORHEA, TEXAS.

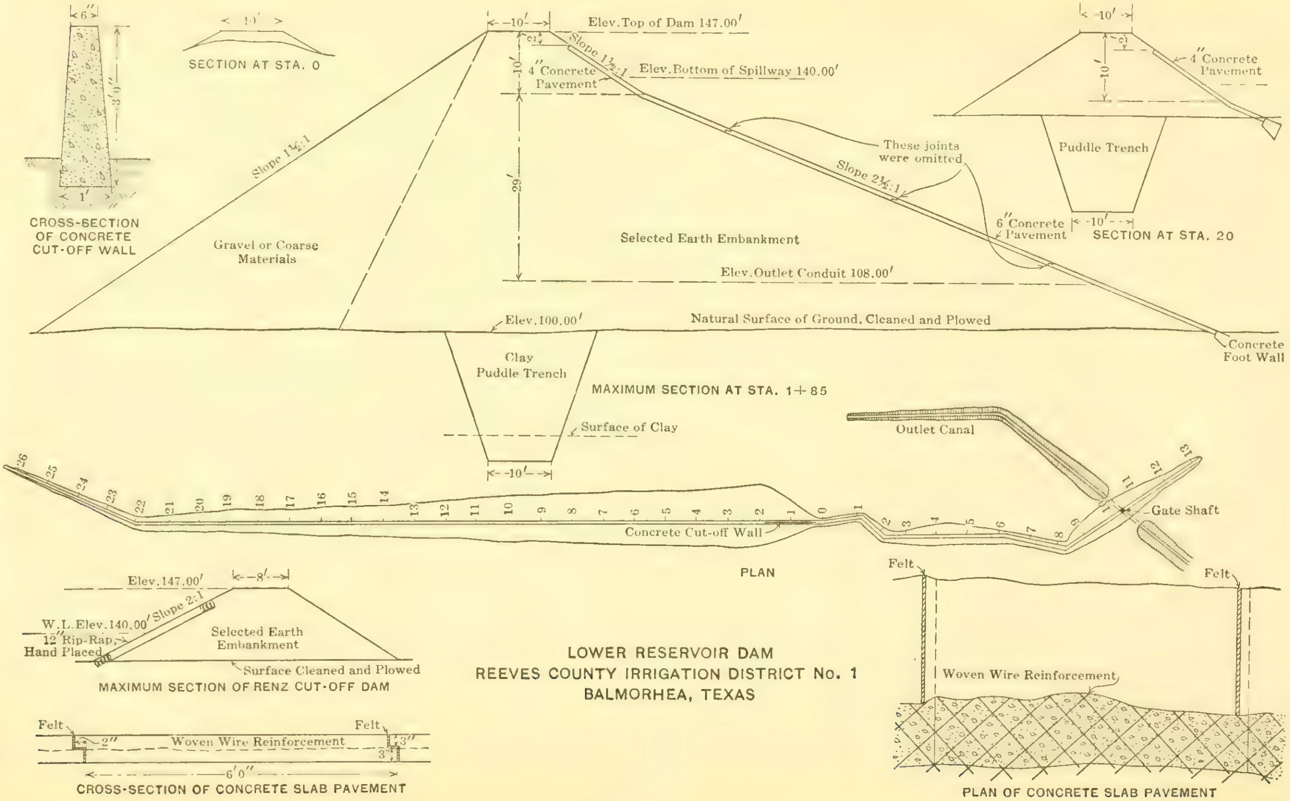
6″
3′0″
1′
CROSS-SECTION OF CONCRETE CUT-OFF WALL
10′
SECTION AT STA. 0
10′
Elev. Top of Dam 147.00′
2′
Slope 1½:1
10′
4″ Concrete Pavement
Elev. Bottom of Spillway 140.00′
Slope 1½:1
29′
Gravel or Coarse Materials
Selected Earth Embankment
These joints were omitted
Slope 2½:1
6″ Concrete Pavement
Elev. Outlet Conduit 108.00′
Elev. 100.00′
Natural Surface of Ground, Cleaned and Plowed
Concrete Foot Wall
Clay Puddle Trench
MAXIMUM SECTION AT STA. 1+85
Surface of Clay
10′
10′
2′
10′
4″ Concrete Pavement
Puddle Trench
10′
SECTION AT STA. 20
Outlet Canal
26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 10 11 12 13
Concrete Cut-off Wall
Gate Shaft
PLAN
Elev. 147.00′
8′
W. L. Elev. 140.00′
Slope 2:1
12″ Rip-Rap, Hand Placed
Selected Earth Embankment
Surface Cleaned and Plowed
MAXIMUM SECTION OF RENZ CUT-OFF DAM
LOWER RESERVOIR DAM
REEVES COUNTY IRRIGATION DISTRICT No. 1
BALMORHEA, TEXAS
Felt
2″
Woven Wire Reinforcement
Felt
3″
3″
6′0″
CROSS-SECTION OF CONCRETE SLAB PAVEMENT
Felt
Felt
Woven Wire Reinforcement
PLAN OF CONCRETE SLAB PAVEMENT

FIG. 7.

ment, and has been found to produce an impervious embankment, it is particularly suited to dam construction.

The spilling point of the reservoir is at Elevation 140, the reinforced concrete paving extends to Elevation 145, and the top of the earth dam when completed will be at Elevation 147. The front or inner surface of the dam is protected from wave action and boring animals by a more or less flexible and practically impervious reinforced concrete paving, as shown by Figs. 5 and 6. A toe-wall, or foot-wall, was built along the inner toe of the dam, to provide a footing for the concrete paving. This paving was constructed in slabs 6 ft. wide, extending from the toe-wall to within 2 ft. of the top of the dam. It is 4 in. thick at the top, or Elevation 145, and increases in thickness uniformly to 7 in. at Elevation 100. The slabs were put in alternately, with the offset or step joint 2 in. wide, running their entire length. The entire surface was reinforced by running heavy wire netting, of about 1 ft. mesh, diagonally across the slabs, and crossing the joints at the same elevation as the step. A thin felt strip, laid over the wire and up the sides of the step joints, provided a parting point between the slabs for expansion. The wires running diagonally through this step joint will provide sufficient give and take in the 2-in. horizontal part of the step for expansion and contraction, without undue strain on the reinforcement. Thus the entire surface of the paving is completely reinforced and bound together in a manner which gives flexibility and provides for expansion.

The dam is built on the least section compatible with good engineering. The back slope is $1\frac{1}{2}:1$; the front slope is $2\frac{1}{2}:1$ from Elevation 100 to Elevation 138, and $1\frac{1}{2}:1$ from Elevation 138 to the top.

The outlet was cut through a low saddle in a string of hills surrounding the reservoir, and from it there is built a reinforced concrete conduit, with double wells, and high-pressure emergency and service gates of standard design. The section and general plan of dam, together with the paving and other details, are shown on Fig. 7.

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PAPERS AND DISCUSSIONS

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OBSTRUCTION OF BRIDGE PIERS TO THE FLOW OF WATER

Discussion.*

By Floyd A. Nagler, Jun. Am. Soc. C. E.†

Mr. Nagler.

Floyd A. Nagler,‡ Jun. Am. Soc. C. E. (by letter).§—The object of this paper was to determine the relative effect of different pier shapes in producing back-water. Some seem to have lost sight of this fact entirely, although it was repeated throughout the paper. The experiments were performed in only one channel, using pier models, each of which obstructed 23.4% of the total channel area. Physical limitations prevented the use of other channel widths, or the use of other ratios of obstruction; therefore the writer gave the following cautions:

> "The coefficients * * * are primarily valuable because they indicate the relative amount of obstruction offered by the different shapes of piers * * *." (Page 839.‖)
>
> "Whether the coefficients for the formula will still have the same value for higher velocities is merely a matter of conjecture * * *." (Page 840.‖)
>
> "The limitations in the size of the flume permitted tests to be made on only one particular width between piers. Whether these coefficients can be extended to other widths between piers is a matter of conjecture * * *." (Page 841.‖)
>
> "Experimental data are not at hand, however, which will assure the accuracy of the formula, if applied to conditions differing widely from those in the writer's experimental flume." (Page 843.‖)

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* Discussion on the paper by Floyd A. Nagler, Jun. Am. Soc. C. E., continued from February, 1918, *Proceedings*.

† Author's closure.

‡ Albany, N. Y.

§ Received by the Secretary, January 23d, 1918.

‖ *Proceedings*, Am. Soc. C. E., May, 1917.

Mr. Nagler. The writer, therefore, has made no guaranty to any reader who blindly applies the coefficients and formulas to conditions differing in their hydraulic proportions from those in the flume described by him. Engineers are too prone to select empirical formulas and coefficients from handbooks and apply them to entirely irrelevant cases, never inquiring as to the natural limitations of the applicability which intelligent use would place on them. Intelligent extension of experimental formulas and coefficients to practical problems is the highest type of engineering, but the blind application of formulas smacks of student days.

The writer's formula, based on what he believes to be the correct theory contains the empirical constants, α, β, and C, the best values for which were determined from this somewhat limited set of experiments in order to present a rational numerical comparison between the different types of piers. It should be evident to any thinking engineer that the coefficients, particularly α and β, would no doubt assume other values under different channel conditions. As no experiments were performed in channels of different widths, the selection of proper values of α and β for other cases is left entirely to the judgment of the engineer. $\beta = 1.8$ is a very high velocity of approach correction, and certainly would be smaller for all channels with a smaller percentage of obstruction offered by the pier than was the case in the writer's flume. It might even assume a value as small as unity for channels in which the bridge pier obstructs only 2 or 3% of the stream. All other bridge pier formulas assume $\beta = 1$ for all conditions. $\beta = 1.8$ is simply the best value of that coefficient for these experiments, or for any other problem where the bridge pier occupies approximately 23.4% of the channel. A simple calculation, using this value of β in the writer's formula, reveals the fact that rational positive results will not necessarily be obtained unless the pier obstructs at least 20% of the channel of approach. Mr. Wiley and Mr. Goodrich seem to have discovered this fact with no little alarm to themselves; but it is as unreasonable to assume that a formula, with one value for the coefficient in correcting for velocity of approach, should fit all varying channel conditions, as it would be to expect the medical profession to produce some concoction which would prove a panacea for all ills.

Only with $\beta = 1$ would it be possible for a bridge pier formula of any of the existing types to be generally applicable; and it is known, from the study of channel contractions caused by weirs, that β is always in excess of unity for weirs of appreciable height. The experiments of Fteley and Stearns show that β assumes a value of 2.05 for channels with almost complete contraction, decreasing to values as low as 1.33 for the lowest weir experimented on, indicating that β would decrease to 1 when there was little or no contraction of the

Mr. Nagler.

channel. The same variation in the value of β would be expected in an adequate bridge pier formula.

In discussing the proper value of β, it is interesting to note, as Mr. Lane suggests, that the writer's formula is quite similar to those of Eytelwein and Debauve. This is true when $\beta = 1$.

Then $$Q = C\,D\,W\sqrt{2\,g\,(H - h_1)}$$

and $$\frac{Q}{D\,W} = V_2 = C\sqrt{2\,g\,H - V_1^2}$$

thence $$H = \frac{C^2\,V_2^2 - V_1^2}{2\,g}$$

in which V_1 = velocity of approach,
V_2 = velocity in contracted pier section,
Q = discharge,
D = depth at pier section,
W = width at pier section,
H = back-water,
C = coefficient.

Messrs. Wiley and Goodrich both give numerical examples in which the writer's formula indicated negative back-water, using $\beta = 1.8$. In both these problems the hydraulic conditions differ widely from those in the writer's flume, and the obstruction to the normal channel was far less than 20%, which is the limit of applicability of the writer's formula, using $\beta = 1.8$. It is evident that a smaller value of β should have been used.

In Mr. Wiley's example, where only 4.7% of the channel area was obstructed, a value of $\beta = 1.04$ would have been selected by the writer, giving a back-water of 0.07 ft., a value very close to that obtained from the actual levels.

In Mr. Goodrich's case, 9.4% of the channel was obstructed, and consequently a value of β of about 1.25 would have been applicable. This gives back-water amounting to 0.14 ft.

In selecting the foregoing values of β, the writer drew a smooth curve (Fig. 22), for different values of channel obstruction, asymptotic to $\beta = 1$ for zero obstruction and $\beta = 2.05$ for 100% obstruction, passing through $\beta = 1.8$ for 23.4% obstruction.

The writer agrees with Mr. Wiley that the value of the coefficient, α, may be found to be other than 0.3 for conditions varying from those in the writer's flume. However, as Mr. Lane observes, the absolute value of this coefficient has but little effect on the results of the computation, especially if the stream depth is appreciable. It is doubtful, therefore, whether speculation as to what other values this coefficient may assume is worthy of comment.

Mr. Nagler. Messrs. Wiley and Lane still favor the use of the Eytelwein and Debauve formulas. If these formulas are generally applicable, they should fit the writer's 256 experiments. They fail to do this. These formulas are at fault in that they consider hydraulic conditions only as far as the point of minimum section, utterly ignoring the static head regained at the tail of the pier when the section is again enlarged. Thus far the stream has suffered very little energy loss, for energy that does not appear in static head is almost all available in the kinetic energy of the water under the increased velocity as it passes the contracted section. The greater loss, in passing the bridge pier section, occurs (beyond the point of minimum section) in the conversion of the increased kinetic energy back into potential energy. It is true that only a small quantity of this energy can be regained, but this is the point where the efficient tail of the pier plays its part, and the writer has demonstrated that the design of the tail actually does affect the height of the back-water. Whether or not this increase in static head becomes a physical fact (Mr. Lane asserts that it more often does not) depends entirely on the hydraulic conditions of the down-stream channel; but, in general, it may be said that in a uniform channel this regain in static head will become apparent in the formation of a standing wave.

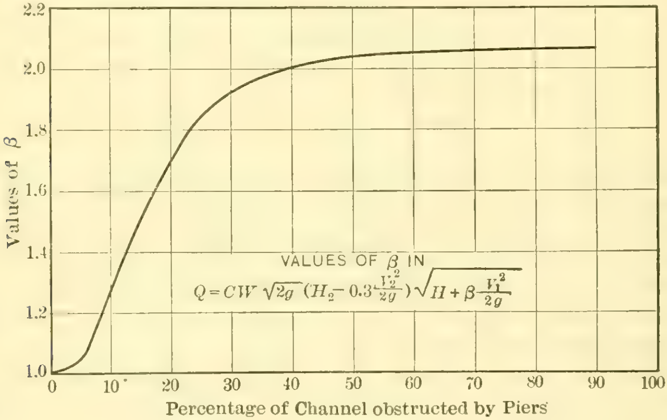

FIG. 22.

In giving a value of less than unity to the coefficients of the Eytelwein or Debauve formulas, a loss greater than that represented by the change in velocity head is anticipated. They are thus only "contraction" coefficients, indicating what further contraction of the section, beyond that of the net width of the stream, is anticipated, and are entirely inadequate for expressing the total loss of the entire phenomena of the contraction and expansion of the section which

Mr. Nagler.

has occurred. The example quoted by Mr. Wiley on page 1549* is illuminating on this point; for, with the use of the D'Aubuisson-Eytelwein formula, he obtained 0.130 ft. for the back-water, whereas the actual back-water was measured as 0.077 ft., only 59% of the computed value. However, 0.15 ft. loss in static head was measured at the point of minimum section, which value coincides more nearly with the back-water computed by the D'Aubuisson-Eytelwein formula.

In reviewing these older formulas, the writer arrived at different conclusions as to their authorship than those apparently expressed in Mr. Hutton's paper, quoted in detail by Mr. Lane. The discussion by Mr. Hutton not only proved inconsistent with other references on this subject consulted by the writer, but also was inconsistent within itself, in that it contains mathematical errors. It will suffice to point out two of these: The statement, $y = \frac{1}{m^2}\left(\frac{v_0 W}{w}\right)^2 - \frac{v_0^2}{2g}$ (page 1559), is correct, according to the premise of Eytelwein, but the equation immediately following it, and offered as a derived equation of the first, is not correct, but should be $y = v_0^2\left(\frac{W^2}{m^2 w^2} - \frac{1}{2g}\right)$ instead of $y = \frac{v_0^2}{m^2}\left(\frac{W}{w^2} - \frac{1}{2g}\right)$. Hutton says, "Eytelwein * * * applies the correction for contraction to the narrow section only." There appears still another error in the statement, $v_{11} = \frac{v_0 Q}{w(h+y)}$; this should have been $v_{11}^2 = \frac{v_0 Q}{w(h+y)}$, for this is the value which is used in the succeeding formula.

Mr. Merriman adopts the formula of A. Debauve,† preferring to call it "Hutton's Formula". Hutton was simply responsible for changing the Debauve formula:

$$y = \frac{Q^2}{2g}\left(\frac{1}{m^2 w^2 h^2} - \frac{1}{W^2 (h+y)^2}\right)$$

to

$$y = \frac{v_0^2}{2g}\left(\frac{W^2}{m^2 w^2} - \frac{h^2}{(h+y)^2}\right).$$

This is only another way of expressing the same theoretical relation, and is accomplished by an algebraic transformation of a single operation. In fact, it is simply the Debauve form of expressing theories already formulated by both D'Aubuisson and Eytelwein. It seems presumptuous for Mr. Merriman to give Mr. Hutton the credit of advancing a new formula on so feeble a premise.

---

* *Proceedings,* Am. Soc. C. E., September, 1917.

† "Treatise on Hydraulics," Tenth Edition.

Mr. Nagler. The writer, however, upholds Mr. Hutton in the reasoning whereby he arrives at this formula, and would call Mr. Lane's attention to the fact that, in the statement "v_0 being the original stream velocity", v_0 does not represent the velocity in the obstructed channel of approach, but becomes equal to the velocity in the channel of retreat. Hence Mr. Hutton is not incorrect when he states:

$$\frac{Q}{w\,h} = \frac{v_0\,W\,h}{w\,h} = \frac{v_0\,W}{w}.$$

For, as v_0 = the velocity in the channel of retreat, and $W\,h$ = the area of the channel of retreat, Q is then equal to the area of the section multiplied by the velocity in that section $= v_0 W\,h$. $v_0\,W\,(h + y)$, which Mr. Lane claims is equal to Q, represents the multiplication of the velocity in the channel of retreat by the area of another section, namely, the channel of approach. This is fundamentally wrong, and the writer is of the opinion that Mr. Hutton is absolutely right.

The writer had hoped that there would be some discussion presenting experimental data as to the effect of the number, size, and spacing of piers offering the same total obstruction. Mr. Lane has stated that he does not agree with the writer, in his conclusion that, in the absence of definite experiments, it would not be unreasonable to assume that there would be no change in the value of the coefficients if the number of piers was increased, retaining the same total obstruction to the stream channel as before; yet he cites, in defense of his position, the writer's illustration of the trash racks, where, regardless of the number, spacing, and size of the individual bars, the loss through the racks was always the same, provided there was always the same total area of obstruction. There should be no disagreement on this point, for the latter is exactly the illustrated conclusion of the writer. The problem itself is a complicated one; for, dividing the total loss in passing a bridge pier into loss at the nose and loss at the tail of the pier, the loss at the nose would seem to increase with the number of piers, though that at the tail would seem to vary inversely as the number of piers. The losses at the nose are revealed in the further contraction of the stream channel beyond the net width at the bridge pier section; assuming, therefore, that the piers are of appreciable size, and, regardless of number, offer the same obstruction to a given channel, the number of these contractions varies directly as the number of piers. On the other hand, if we consider the losses at the tail of the pier to be represented by the volume of the triangular prism of eddying water at the down-stream end, this volume, and consequently the losses, varies inversely as the number of piers, being greatest for a single pier, then decreasing as the piers increase in number, and disappearing entirely if we assume an infinite number of piers. This

Mr. Nagler.

proposition is of easy geometrical proof. These two opposite tendencies in producing loss in a bridge pier section, if the number and width of piers is varied, maintaining the same total net obstruction to the stream, tend to counterbalance each other; whence the coefficient to be applied in solving for the height of back-water might be the same, regardless of the number of piers. It is to be hoped that large-scale experiments will be performed in the near future, which will settle this question. However, the writer does not anticipate, as Mr. Fowler desires, that it will be possible to perform a set of experiments on a large scale duplicating actual conditions encountered in practice. Such a set of experiments would be almost inconceivable, if it were required that all actual bridge pier conditions be duplicated, for bridge pier sections seldom even duplicate themselves. The main value of the set of relative coefficients offered by the writer lies in the fact that they establish a basis on which an intelligent engineer may select a coefficient which will apply to the modifications in the problem at hand. For instance, he may readily estimate how effective a square crib near the channel bottom may be in reducing the coefficient of a round-nose pier; or may arrive at a reasonable coefficient (approximately 0.88) for the Fowler patent reinforced concrete pier.

The writer's experimental data are filed in the archives of the Society. Mr. Goodrich states that the "well known and experienced hydraulic engineer employed by the city", to whom he refers, had access to these data, and, the writer is informed, used them in arriving at his conclusion that the obstruction in the case cited would cause back-water amounting to about 1 in. The writer cannot conceive how Mr. Goodrich computed the value of 3 in. of back-water in his first set of calculations. The value by the formula, with a velocity of approach correction equal to unity, should give the maximum possible results, and certainly larger than the writer's formula with a coefficient of 1.8, which Mr. Goodrich says he used. The highest thus obtainable is but little more than 2 in., and the writer is of the opinion that the original claim of 3 in. of back-water fails to have the support of any computations by the writer's formula.

The writer notes that although Mr. Merriman states that the profile of Fig. 13, copied from the ninth edition of his "Treatise on Hydraulics", represents "approximately an average of all the profiles between two piers", in the tenth edition there is shown, in its place, what the writer considers to be a more rational average profile, in that depression of the water surface does not begin until the water reaches the nose of the pier.

The value of Kutter's *n* used by the writer in Fig. 10 was 0.009, a value applicable to timber channels, well planed, and perfectly continuous.

Mr. Nagler.

The writer cannot agree with Mr. Horton in that Gauge No. 3 "should have been placed at the same distance up stream, or else at a greater distance than that of Bazin", on account of "velocity of approach and surface curvature". Though the writer believes that the gauge should always be placed up stream beyond the point where it would be affected by surface curvature, it must also be far enough up stream not to lie within "the angle of pressure". Fteley and Stearns* found that heads measured within this angle might exceed the true static head by as much as 2.5 times the velocity head of approach. They furthermore state:

> "It is deemed reasonable and fairly in accordance with them [the experiments] to assume that the distance [upstream terminus of the angle of pressure] varies with the height of the weir above the bottom of the channel, and that it is about 2½ times this height."

It was for this reason that the writer adopted the formula of measuring the head at a distance up stream from the weir crest (as compared with Bazin's point of measurement) proportional to the ratio of the height of the weir crest to the height of the weir used by Bazin. This same formula was used in measuring the head on one of the Cornell weirs, with which the writer understands Mr. Horton is thoroughly familiar. Richard R. Lyman, Assoc. M. Am. Soc. C. E., has explained this also.†

Since the presentation of the paper the writer has had occasion to perform extensive experiments in order to determine any appreciable evidence of surface curvature farther than 6 ft. from a suppressed weir, 6.56 ft. long and 3.72 ft. high. Gauges established 6 ft., and also 16.4 ft., from the weir recorded the same head for velocities of approach as high as 4 ft. per sec. (4 ft. head on the weir). As the velocities in the writer's experiments hardly exceeded this value, he is of the opinion that Gauge No. 3, established 10.625 ft. from the weir, recorded the correct head on the weir.

The writer is of the opinion that the proper procedure in investigating the effect of any single variable on an equation or phenomenon involving many variables, is either to eliminate all other variables or regulate them so that they become constants. This was precisely the writer's method in determining the relative effects of different shapes of piers; hence Mr. Molitor's incredulity in doubting that even this fact was demonstrated by the experiments seems almost inconceivable. Certainly, the only physical phenomenon which did change the size of the coefficients in the formula was the changing of the shape of the piers; and if this is not demonstrating the relative effect of the different designs, the writer is at loss to know by what name to call it.

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* *Transactions*, Am. Soc. C. E., Vol. XII, p. 46.

† *Transactions*, Am. Soc. C. E., Vol. LXXVII, p. 1271.

Mr. Nagler.

Mr. Molitor makes the criticism that all the variables encountered in practice have not been imposed as a test for the writer's empiric constant. It is true that the effect of varying the percentage of obstruction offered by the pier was not investigated. This was unnecessary in the determination of the "effects of the different pier shapes"; but the writer even went further than this one objective, and studied the effect of the variables of depth and velocity, thus putting any bridge pier formula to a more severe test than had been applied by any experimental work to date. The writer's empiric constant withstood this test, others did not, but varied as much as 9% for any one pier. If the empiric constants for these other formulas varied this much in the consideration of only two of the variables involved, common sense dictates that the variation might even be greater when put to the test of encountering all the variables known to practice. Therefore the writer can see no grounds on which Mr. Molitor might base his "emphatic objection" to the writer's first conclusion that error exists in the present bridge pier formulas. A study of the original data for these experiments perhaps might satisfy Mr. Molitor, as he could then test the futility of obtaining an empiric constant for these existing formulas.

Although the heading-up above the pier in the writer's flume occupied a relatively greater width of the free channel than in most practical conditions, the writer cannot agree with Mr. Molitor that this phenomenon was effective in producing error in the results, as the points of measurement of static head both up stream and down stream from the pier section, were several feet remote from any local disturbance of this sort caused by the pier, and were thus statically unaffected by these disturbances.

The writer was not aware of the inconsistency in his use of symbols until Mr. Molitor brought this to his attention. It is true that there appears to be an error in the algebraic substitution on page 838, whereas if correct symbols had been used there would be none. The H_d as used on page 838 should be understood to mean the "measured head" instead of the "drop in the flume" as formerly used; and again, the H in the writer's final formula should have borne the subscript, d. Hence the writer's formula should not be mistaken to give the "drop in the flume" (that would be ludicrous), but gives, as he claimed, the rise or back-water caused by the pier.

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PAPERS AND DISCUSSIONS

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AIR TANKS ON PIPE LINES

Discussion.*

By Minton M. Warren, Assoc. M. Am. Soc. C. E.†

Mr. Warren.

Minton M. Warren,‡ Assoc. M. Am. Soc. C. E. (by letter).§—The writer was much gratified to find that his formulas for air tanks had been verified by Professor Church, and by actual data of Mr. Wahlman, in the case where they were properly applied. He also wishes to thank Mr. Johnson and Mr. Jorgensen for their discussions.

The formulas and object of the paper have been somewhat misunderstood, as the formulas were offered merely as a guide to air tank design, and to be used only with the full realization of the assumptions on which they were based. Any engineer applying them must, of course, use his judgment in fitting them to the special case he is designing.

As far as the writer knows, no useable formula of any kind has been offered for air tank design, and these are presented as a start for such computations. As governor action, wheel efficiency, friction, etc., cannot be neglected, the results must be modified in each particular case, and differential devices, valves, or orifices, must be used in order to prevent surges and aid regulation.

Before publication the formulas were checked by the results of an actual operating air tank which had been very successful in removing trouble caused by surges and water-hammer in a large power plant.

These data are not at present available to the writer, but the results of actual tests of a new air tank design along these lines will soon be ready, and when published should give valuable information on this subject.

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* Discussion of the paper by Minton M. Warren, Assoc. M. Am. Soc. C. E., continued from December, 1917, *Proceedings*.

† Author's closure.

‡ Cambridge, Mass.

§ Received by the Secretary, March 27th, 1918.

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PAPERS AND DISCUSSIONS

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THE SUBSIDENCE OF MUCK AND PEAT SOILS IN SOUTHERN LOUISIANA AND FLORIDA

Discussion.*

By Messrs. S. H. McCrory and Charles W. Okey.†

S. H. McCrory,‡ M. Am. Soc. C. E. (by letter).§—Since the paper was written by Mr. Okey a number of the profiles have been run again. The data obtained show that subsidence has occurred in each district where the profiles have been repeated. In some districts it has been small, in others quite large. In the Little Woods Drainage District in Orleans Parish, Louisiana, the water was held low in the canals and the soil was well drained; however, the new profile shows very little additional subsidence. Undoubtedly this is due to the fact that the tract has been drained for 5 to 7 years, and the surface soil has been quite thoroughly compacted by drying, decay, and cultivation. It appears, as would be expected, that the subsidence and its rate depend largely on the depth of drainage, and that the rate is most rapid immediately after the drains are constructed or are deepened. Mr. McCrory

Subsidence occurs in all muck and peat soils when they are drained, and this must be taken into account when the drainage of such soils is planned. The writer has examined projects in North Carolina, New York, Michigan, Minnesota, and California, where drainage systems have been made ineffective by this lowering of the ground surface. The muck and peat areas usually are nearly level, and when gravity outlets are used for drainage the grades of the drains are very flat.

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* Discussion of the paper by Charles W. Okey, Assoc. M. Am. Soc. C. E., continued from February, 1918, *Proceedings*.

† Author's closure.

‡ Washington, D. C.

§ Received by the Secretary, March 5th, 1918.

Mr. McCrory. Under such circumstances, lowering the surface only a few feet will decrease seriously the cross-section and the capacity of the ditch, thereby requiring that the drain be deepened or, in some cases, that pumping plants be put in. If the layer of muck or peat is not deep and it is underlain by a good soil, subsidence usually will not be a serious matter; but when this top soil is of considerable depth, or is underlain by hard rock or sand, the construction of a drain that will be permanently satisfactory may be impossible.

The information that the writer has been able to obtain in regard to subsidence of muck and peat soils in the Northern States is rather meager, but apparently the percentage is about the same as in the Southern States, though the rate is somewhat slower.

Mr. Okey. CHARLES W. OKEY,* Assoc. M. Am. Soc. C. E. (by letter).†—The discussion contributed by Mr. Morgan furnishes further valuable information in regard to the characteristics of muck and peat soils, and makes clear the fact that there is a great difference in them, which, of course, is due to the circumstances under which they were formed. Although there are variations, due to the nature of the vegetable life which furnished the vegetable content of the soil, the principal factor to be considered is whether or not the waters near which, or in which, the muck or peat is formed carry silt from other locations into or over those areas. Muck and peat soils are formed in poorly drained areas lower than the surrounding land, and therefore receive the drainage from the higher areas. In relatively small areas of such soils, and particularly when the surrounding slopes are pronounced, there is a heavy percentage of silt. On the other hand, in large areas, such as border the coast of the Atlantic States, as exist in Minnesota, Florida, and Southern Louisiana, the mineral content is low, except for overflows of the larger silt-bearing streams. The soils of Southern Louisiana have a relatively high mineral content because the Mississippi River, with its enormous burden of silt, has actually formed a good portion of the State of Louisiana, and the river has been able to furnish enough flood waters to reach practically every portion of the alluvial region. On the other hand, the Everglades of Florida have been formed in clear waters, and, except for a small strip along the southern shore of Lake Okeechobee have received no alluvial deposit.

Although the percentage of ash was not determined for the soils examined, samples in sealed containers were sent to the Office of Public Roads and Rural Engineering by the writer when the investigations were made, and, if these samples have been preserved, the determination could yet be made.

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* Whitehall, S. C.

† Received by the Secretary, March 27th, 1918.

Mr. Randolph makes this statement: Mr. Okey.

"It would appear * * * that the subsidence of saw grass muck, * * * takes places somewhat uniformly over the entire depth of muck, and that it is not confined to that portion of the muck which stands above the water-table."

In the sentence following he also states:

"It also appears that the depth of subsidence due to this cause is dependent on the depth to which the water-table has been lowered, * * *."

On their face, these two statements appear to be contradictory, but perhaps Mr. Randolph's intention is not quite clear. The writer agrees with the second statement, but thinks that the portion of the muck which is permanently saturated does not show any appreciable change.

In securing the samples for determining their weight, the writer used sheet-iron cylinders, 4 in. in diameter, 4 in. in length, and open at both ends. The cutting end was sharpened, and the sample was secured by forcing the cylinder vertically into the soil. Samples were taken from the top downward, in such a way as to get a continuous column. As water was usually present either on or in the soil, it was not practicable to go very deep. However, as shown by the profiles, in most cases in Southern Louisiana it was possible to get through the top soil to the underlying alluvium. Especially on soils which had never been cultivated, the cutting of the first sample was somewhat difficult, due to the presence of tough roots. As a result a certain amount of compacting occurred, and the 4-in. sample represented a slightly greater depth, as the cutter was always forced into the earth until the material was level with the top. Even in the subsequent samples there was a small amount of compacting, due to the friction of the material entering the cutter. Consequently the sample in the cutter actually represented a slightly greater volume of the material in its original state. Therefore the calculated weight per cubic foot would be slightly in excess of the actual. It is considered likely that the error is greatest on the lightest and softest materials, as they were compacted most when samples were taken.

Mr. Hering's discussion is applicable to such soils as are found in New Orleans and in rather close proximity to the Mississippi River. These are almost entirely alluvium, and, in comparison with the muck and peat lands, contain very little vegetable matter. Although the areas numbered 35, 36, and 37 on the map are not far from New Orleans, the soil conditions are entirely different, at least so far as the portion of the city near the river is concerned.

The material described by Mr. Lyle is evidently well-decayed muck —at least the upper portion. It would be very interesting to have observations repeated on this piece of work in the future.

Mr. Okey.

The discussion contributed by Mr. McCrory is exceedingly interesting, as it shows the additional settlement in the districts, examined by the writer 2 years before. The measurements were made by other observers, and the writer did not know of the results. It is to be hoped that the work will be continued. After a period of about 5 years, or in 1920, the writer believes that it would be of value to have samples of the soil taken under the same conditions as in 1915.

The writer is very grateful for the favorable discussion contributed by the several members. Mr. Morgan, Mr. Kimball, and Mr. McCrory have each put special stress on the importance of anticipating the subsidence of muck and peat soils in the design of drainage improvements. The writer agrees with these gentlemen in every point they have made. It is now a certainty that, unless provision is made for such subsidence, there is trouble in store for the owners of lands such as these, which are drained by channels adequate only if the surface maintains its original elevation.

The writer regrets that engineers who are responsible for the design of drainage improvements for some of the largest areas of muck and peat lands in the world have not been contributors to the discussion. At the time the paper was opened for discussion the writer furnished a list of names of members who were directly interested in such work, and these members were requested by the Secretary of the Society to discuss the paper or to offer such material as they had available on the subsidence of muck and peat soils. Discussion from those engineers, responsible for the drainage of such great areas of lands, would be of the highest interest. The writer feels that the membership would then receive the benefit of the practical application of the facts, in regard to the subsidence of muck and peat soils, to the concrete problems presented in the design of drainage improvements. It would be exceedingly interesting and instructive to know what provision is being made for subsidence in the design of these great works, in which millions of dollars will ultimately be expended, and on which thousands of farmers will depend for adequate drainage. It is to be hoped that such discussion will be forthcoming.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

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THE HELL GATE ARCH BRIDGE AND APPROACHES OF THE NEW YORK CONNECTING RAILROAD OVER THE EAST RIVER IN NEW YORK CITY

Discussion.*

By Gustav Lindenthal, M. Am. Soc. C. E.

Mr. Lindenthal

Gustav Lindenthal,† M. Am. Soc. C. E. (by letter).‡—Mr. Breithaupt believes that for Little Hell Gate either spandrel-braced or double-ribbed arches should have been used, in place of the inverted bow-string type.

There is no navigation on this short stream, except that of small pleasure launches and sailing boats. The clear height above the water was of less importance, in the opinion of the Government engineers, than the obstruction from piers. It is expected that this channel (which connects the East River with the Harlem River) will be deepened, not for purposes of navigation, but for a more ample flow of the tides through it. Long piers in the direction of the currents were regarded as offering more obstruction to the tidal flow than the column piers as arranged. Metal arches in place of bow-string girders would have required heavier column piers to take up the resultant between loaded and unloaded adjacent spans. There would have been, not only no saving in the total cost of this crossing, but more obstruction to the current.

For an arrangement of four continuous spandrel-braced arches, delivering only vertical pressure on the river piers and subject to heavy temperature stresses, violent reversion stresses, and large secondary stresses, the relation of live load to dead load was not favorable. It is not an arrangement suitable to a railroad bridge.

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* Discussion of the paper by O. H. Ammann, M. Am. Soc. C. E., continued from March, 1918, *Proceedings*.

† New York City.

‡ Received by the Secretary, March 19th, 1918.

Mr. Lindenthal. At first, parallel-chord, riveted trusses were considered, but most of the members were so large as to require cross-sections with four webs. That is very objectionable in tension chords. The inverted bow-string girder, with the tension chord composed of eye-bars, made a more satisfactory structural arrangement. The web stresses in this form of truss are small, and the details for them simple. The eye-bars are the heaviest ever forged—16 by 2¼ in., with 16-in. pins.

The superstructure receives its lateral rigidity through an extra heavy and rigid wind and vibration truss in the plane of the top chords. It is sufficient to transmit the wind pressure, which acts on the bottom chord at each vertical web member, by a stiff diagonal to the wind truss above; therefore, no bracing is required in the bottom chord. The correctness of this detail is proved, also, by the fact that the bridge is laterally quite rigid under trains. The rigidity of the superstructure is further enhanced by the fact that its center line of gravity is about 15 ft. below the points of support on top of the piers and abutments. It would be in stable equilibrium, therefore, even without any lateral bracing below the wind truss.

It will be noticed, in the silhouette of the bridge, that its floor-table has the same thickness (10 ft.) as the plate-girder approaches. The harmony of design is thus preserved. That uniformly deep floor-table forms a continuous heavy line on top of the masonry piers; it appears on this structure at a distance, as if supported on slim catenary chains, but, in fact, these chains each form the heaviest eye-bar chord member in any existing, simple-span, truss bridge.

The masonry tower piers at each end of Little Hell Gate form a sufficient break to mark the longer spans. These towers are hollow, and contain emergency stairways. Their form, it is true, could have been somewhat improved, had they been studied in a model, as was done in the case of the granite towers for the large arch span.

The writer would have preferred to make provision from the start for a second deck throughout for a boulevard over the railroad tracks, which he foresaw would be wanted in the future for highway traffic between the Bronx and Long Island; but his efforts at that time to get the public and city authorities interested in a boulevard were not successful, and were also not favored by the Railroad Company. The time will come, however, when such a boulevard may be added. It will be cheaper to do that than to build a separate parallel structure for that purpose.

Contrary to Mr. Quimby's opinion, the span length of the concrete viaduct is not too short. As stated in the paper, the most economical length was chosen, except where affected by the location of the streets. By examining the costs of masonry and steelwork given, Mr. Quimby can easily convince himself of this fact.

Mr. Lindenthal.

An important reason for adopting the concrete piers was that objection was made by the authorities of Wards and Randalls Islands to the steel columns, because they feared that inmates of the municipal institutions on those islands would climb them and make their escape. It was insisted that the design adopted should prevent this.

Mr. Quimby's idea as to what should have been the arrangement of the end panel in the large arch is based on an erroneous assumption. Assuming that the top chord of the arch would be anchored in the towers, making of the arch a type with fixed ends and end moments, a diagonal member to the end of the top chord would be entirely superfluous, and would appear so to the technically trained eye, as the shearing stress would be taken care of by the masonry. The anchoring of the top chord, however, would have required much heavier stone towers, and of different form, in order to take up the horizontal anchorage stresses at the top.

The top chord was prolonged into the masonry simply for convenience of inspection. There is a little stairway hidden in the end of the deep top chord over which one is enabled to enter from the interior of the tower and go out on the chord. The objection of the Municipal Art Commission to the first design was merely against the too ornate form of the towers of moulded concrete. The form of towers, therefore, was simplified, and granite was chosen for the exterior faces.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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STRESS MEASUREMENTS ON THE HELL GATE ARCH BRIDGE

Discussion.*

By Messrs. F. E. Turneaure, Henry S. Jacoby, and O. H. Ammann

Mr. Turneaure.

F. E. Turneaure,† M. Am. Soc. C. E. (by letter).‡—The measurements on the Hell Gate Bridge are of great value, not only in connection with the determination of stresses in that structure, but also as an important contribution to our knowledge of the amount of secondary stress actually existing in structures. The writer does not believe that it will ever be necessary or desirable to calculate secondary stresses in the ordinary practice of bridge design; but he does believe that their consideration, both theoretically and experimentally, in such unusual structures as the one under consideration, is of very great importance. The more accurate our information may be concerning the various kinds of stresses which exist in a structure, the more safely and economically can such a structure be designed; and, although the extra margin of safety required to take care of uncalculated and indeterminate stresses may not be a very serious matter in structures of ordinary size, it becomes of extreme importance in those of very large size. Both safety and economy demand that as complete knowledge as possible should be obtained concerning all the elements involved. Secondary stress is one of those elements; and, although ordinarily not as large as the primary stress, and not as readily and accurately determined, it is, in many cases, quite comparable in amount, so that it cannot be ignored without making a very large allowance in the margin of safety.

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* Discussion of the paper by D. B. Steinman, Assoc. M. Am. Soc. C. E., continued from March, 1918, *Proceedings*.

† Madison, Wis.

‡ Received by the Secretary, March 15th, 1918.

Mr. Turneaure.

Although the measurements made by Mr. Steinman show a very considerable discrepancy between the calculated and observed values, yet, taking everything into consideration, they constitute a very satisfactory experimental check of calculated results. Nor is it surprising that a very considerable amount of the secondary stress, as measured, was found to be caused by other factors than the bending of the members in the plane of the truss, which is that part of the secondary stress subject to calculation. In tests made by the writer, the same result was obtained in many cases, but where conditions were perfectly symmetrical, the experimental and calculated results agreed very well.

It does not seem to the writer that it is quite safe to draw conclusions relative to secondary stresses in ordinary trusses from the results on the Hell Gate Arch. It is apparent that the arch as designed is in a very favorable condition relative to secondary stresses when under either full dead or full live load. Under such load the main arch rib or lower chord receives its maximum stress, and, therefore, the significant secondary stresses in this member will be those occurring for this condition of loading; but, when the structure is thus loaded, the upper as well as the lower chord is in compression, and the web members are not very highly stressed. This condition results in comparatively low secondary stresses in the chords, much lower relatively than those which occur in an ordinary truss in which the lower chord is in tension and the upper chord is in compression. In the latter case there will evidently be greater distortion of joints than where the chords are subjected to the same kind of stress. As an illustration of a most favorable condition, consider the legs of an elevated water tank If these are made straight and are centrally loaded at each end, there will be practically no secondary stress except for wind pressure. It would appear, therefore, that the secondary stress to be anticipated in the main chord of the arch would be relatively small, as results of measurement as well as calculations show to be the fact. Calculations also show that, for a live load covering a half span, the secondary stresses reach fairly large values, but these are of no particular significance for the main chord, as the primary stresses for this condition are small. It will be noted on Plate XXXVIII that the calculated secondary stresses for this condition of loading reach a value as high as 2 000 lb. per sq. in., which is an indication of what may readily occur in other types of structures where the maximum primary stress occurs at the same time. It would seem, therefore, that no general conclusions can be drawn from these calculations and measurements which can be safely applied to other types. It probably was not Mr. Steinman's intention to suggest that such application could be made, but a statement on page 1828* might possibly be interpreted in this direction. His suggested figure of 25%

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* *Proceedings*, Am. Soc. C. E., October, 1917.

Mr. Turneaure.

+ 4 000 would probably cover most cases of well-designed structures, but the writer would hardly agree with his suggestion that a proper way to treat the matter would be to deduct this from the minimum elastic limit of the material and then use the remainder as a safe working stress for bridge members. There are other things besides secondary stresses which need to be considered in determining the working stresses, and care should be taken to make one step at a time. If it is found that the secondary stresses in any particular structure can be represented safely by a particular percentage of the primary stresses or a percentage plus a constant, then we have arrived at a fair value of the maximum fiber stress, and are much better prepared to discuss the subject of working stresses than if no estimate of the secondary stresses had been made.

It is evident that secondary stresses are much more serious with respect to compression members than tension members, and the precautions taken in the construction of the Hell Gate Bridge to secure fairly concentric loading of segments should be effective in preventing any very extreme secondary stress. Assuming the pressures along the line of contact of the webs (one-third of their width) to vary as much as from zero at one edge to a maximum at the other, the greatest secondary stress which could be produced under such conditions would be approximately 35 per cent. It was to be expected that the actual stresses would be much less than this.

The great care taken in the design and erection of the Hell Gate Arch and the special precautions observed in other large structures of recent design show the increasing appreciation of the importance of scientific methods of design and accurate fabrication of important structures. Where such conditions prevail, the objection to the use of statically indeterminate structures, which has been so general in the past, loses its force, and there would seem to be no reason for excluding such forms of structure where, for other reasons, they are desirable. These are often called indeterminate structures, but such is not the case. They are simply statically indeterminate, and the calculation of the stresses requires a little more work than for structures that are statically determinate. The results of calculation, also, are not quite so accurate, as they are affected somewhat by temperature variations and inaccuracy of fabrication; but they have exactly the same degree of accuracy as the calculations of deflections of statically determinate structures, and it is well known that deflection calculations are very reliable. The same comments hold true, to a large extent, with reference to secondary stress, and such stresses are just as much a real part of the total stress which may prevail in any fiber of a member as the primary stress; and they are just as certain to exist as it is certain that the structure will deflect under load. The accuracy of their determination, however, is not so great as that of the primary stresses, on

Mr. Turneaure. account of the indeterminate effect of temperature variations and of joint plates, rivets, and other details.

The very excellent and painstaking work represented by this paper should be an example of what can be done in the scientific treatment of important structures, and the value of the results secured should serve as a strong incentive to other engineers to conduct similar investigations.

Mr. Jacoby. HENRY S. JACOBY,* ASSOC. AM. SOC. C. E. (by letter).†—By having stress measurements made on the Hell Gate Arch Bridge during its erection, an important service has been rendered to the Engineering Profession. The design of bridges, as well as other structures, cannot be carried out with the highest regard to both security and economy without the aid of continuous scientific investigation. When observations are made on an actual structure, especially one in which the members are so large and where the resources of construction in equipment and workmanship are taxed to a much higher degree than usual, the results are of far greater value than laboratory experiments could possibly give.

The Chief Engineer, Mr. Lindenthal, therefore merits the appreciation of every engineer who is actively interested in the progress of bridge design and construction, for deciding to take advantage of this unique opportunity. If a larger number of engineers in charge of construction were willing to combine a relatively small amount of scientific research with important works in construction, the rate of engineering progress would be materially increased. The value of the results thus secured, under wise direction, may be far greater than the extra financial outlay involved. The author deserves credit for the systematic form in which the paper is presented. It is gratifying to learn that the actual secondary stresses were found to be lower than the computed values.

As a part of this discussion it may be interesting to present the computed secondary stresses in a two-hinged, spandrel-braced arch with cantilever arms. The design of the arch and of the adjacent suspended spans, a critical discussion of various methods for determining the primary stresses, and the computation of the secondary stresses, were presented to the Faculty of the Graduate School of Cornell University as a thesis for the degree of M. C. E. by Mr. Thomson Mao in June, 1917.

The general dimensions of the trusses, and the dead panel loads, expressed in kips or units of 1 000 lb., are shown in Fig. 15, and the notation used for the truss members, the live panel loads, and the joints, is shown in Fig. 16. The live panel loads on the right half of the arch are 7, 8, 9, 10, 11, and 12, while those on the right cantilever are 11′ and

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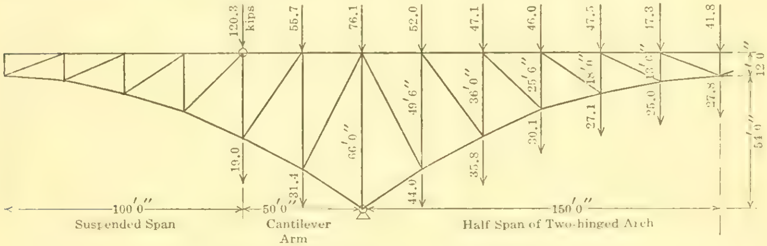
* Ithaca, N. Y.

† Received by the Secretary, March 14th, 1918.

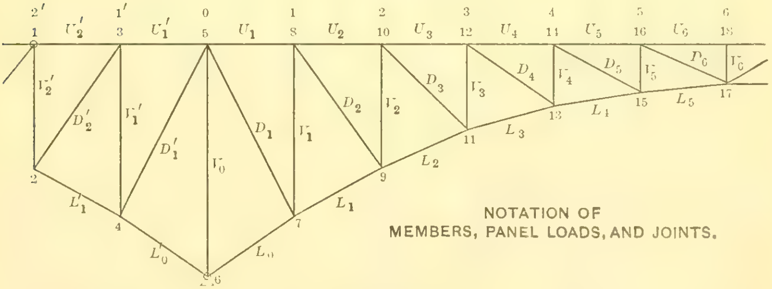
Mr. Jacoby.

10′. Various properties of the truss members required in the computations are given in Table 7. The revised primary stresses in the members of the half arch and a cantilever arm are given in Table 8. The live panel load per truss is 141.6 kips, the panel load 2′ at the end of the cantilever being 445.8 kips, of which 375.0 kips equals the reaction of the suspended span. The impact was computed by the formula $I = \frac{300\,S}{(300 + L)}$, in which I is the impact stress, S is the live-load stress, and L is the loaded length producing the greatest live-load stress. The stresses due to temperature were computed for a range of ± 75° from the mean. The wind stresses were found to be less than 25% of the other stresses, except in the two upper chord members of the cantilever arm. These two members have a large excess of section, as the section of the upper chord is the same for five panels.



GENERAL DIMENSIONS, AND DEAD PANEL LOADS.

FIG. 15.



NOTATION OF MEMBERS, PANEL LOADS, AND JOINTS.

FIG. 16.

The secondary stresses were determined by what is known as Mohr's method, in which displacement diagrams are constructed to find the change in slope of truss members. In applying the method, it was planned to find the primary stresses in all the members of the arch and its two cantilever arms for a load of 1 kip at each of the panel points from one end to the center of the span. As the secondary stresses are directly proportional to the magnitude of an external load in any given position, labor was saved by choosing the vertical loads at differ-

Mr. Jacoby.

ent panel points so as to give a vertical upward reaction of 1 kip at the left support. Ten cases were taken. In the first case the stresses were found for a horizontal reaction of 1 kip; in the other nine cases the stresses were found for vertical loads as follows: 1 kip for panel load No. 0; 2 kips for panel load No. 6; 2.4 kips for No. 7; 3 kips for No. 8; 4 kips for No. 9; 6 kips for No. 10; 12 kips at No. 11; 12 kips upward for No. 11′; and 6 kips upward for No. 10′. The stresses for a panel load of 1 kip at each panel point were found from the foregoing by combining the stresses due to corresponding vertical and horizontal reactions.

After the values of various terms required by Mohr's method for secondary stresses were obtained, the equations were formed for every joint of the truss for each case of loading. Accordingly, it was necessary to solve ten sets of thirty-four simultaneous equations. They were solved by the method of Gauss, as they have the same form as the normal equations in geodesy. This fact was first noted by Mr. José Páez, a graduate student at Cornell University in 1912-13, who combined a minor in geodetic engineering with his major subject in bridge engineering. Mr. Páez wrote a thesis on secondary stresses in which he made a critical comparison of all known methods for their computation, and applied each of them to the same truss. He also discovered an additional approximate method. By the method of Gauss, the solution of the equations becomes quite mechanical, and may be

TABLE 7.

Truss members.	Length, in inches.	Section area, in square inches.	Least radius of gyration, in inches.	Values of $\frac{2c^*}{l}$.	Values of $\frac{2c}{l}$.	Truss members.	Length, in inches.	Section area, in square inches.	Least radius of gyration, in inches.	Values of $\frac{2c}{l}$.
U_2'	300	77.2	12.90	0.0936†	0.1145‡	D_2'	526	51.37	6.95	0.0381
U_1'	300	77.2	12.90	0.0936	0.1145	D_1'	665	51.37	6.95	0.0301
U_1	300	77.2	12.90	0.0936	0.1145	D_1	665	38.13	7.11	0.0301
U_2	300	77.2	12.90	0.0936	0.1145	D_2	526	35.63	7.19	0.0381
U_3	300	77.2	12.90	0.0936	0.1145	D_3	428	35.63	7.19	0.0467
U_4	300	99.2	10.00	0.0956	0.1122	D_4	370	38.13	7.11	0.0541
U_5	300	99.2	10.00	0.0956	0.1122	D_5	341	53.86	6.87	0.0587
U_6	300	99.2	10.00	0.0956	0.1122	D_6	332	63.05	6.78	0.0602
L_1'	341	49.0	9.73	0.1172	......	V_2'	432	65.3	8.80	0.0578
L_0'	360	73.4	10.10	0.1111	......	V_1'	594	77.8	9.13	0.0442
L_0	360	195.8	10.30	0.1111	......	V_0	792	118.4	8 70	0.0341
L_1	341	185.8	10.30	0.1172	......	V_1	594	65.9	9.02	0.0438
L_2	325	185.8	10.30	0.1230	......	V_2	432	44.0	8.57	0.0578
L_3	313	175.8	10.25	0.1278	......	V_3	306	44.0	8.57	0.0817
L_4	305	175.8	10.25	0.1310	......	V_4	216	44.0	8.57	0.1156
L_5	301	153.4	10.30	0.1328	......	V_5	162	44.0	8.57	0.1542
						V_6	144	29.5	6.95	0.1388

* c = distance of outer fiber from neutral axis, and l = length of member.

† Upper side of member.

‡ Lower side of member.

Mr. Jacoby.

TABLE 8.—REVISED PRIMARY STRESSES.

	U_2'	U_1'	U_1	U_2	U_3	U_4	U_5	U_6
Dead load	0	+ 70.4	+ 117.3	+ 97.2	+ 73.8	+ 43.8	+ 13.3	0
Live load	0	+ 225.3	+ 489.1	+ 582.1	+ 652.4	+ 622.6	+ 406.6	+ 217.9
Impact	0	+ 122.7	+ 154.3	+ 183.1	+ 211.1	+ 208.5	+ 143.2	+ 72.6
Temperature (rise)	0	0	+ 24.6	+ 61.7	+ 117.4	+ 197.2	+ 288.0	+ 332.7
Live load	0	0	— 150.3	— 322.3	— 511.6	— 653.4	— 640.4	— 511.2
Impact	0	0	— 54.6	— 115.1	— 176.3	— 219.2	— 203.3	— 170.1
Temperature (fall)	0	0	— 24.6	— 61.7	— 117.4	197.2	— 288.0	— 332.7
Maximum	0	+ 418.4	+ 785.3	+ 924.1	+ 1 054.7	+ 1 072.1	— 1 118.4	— 1 014.0
Minimum	0	+ 70.4	112.2	— 401.9	— 731.5	— 1 026.0	+ 851.1	+ 623.2

	L_1'	L_0'	L_0	L_1	L_2	L_3	L_4	L_5
Dead load	79.9	— 166.1	718.2	— 655.5	— 602.5	— 557.6	— 511.3	— 474.7
Live load	— 256.2	— 468.4	— 1 487.6	— 1 410.3	1 340.8	— 1 257.4	1 081.8	— 778.9
Impact	— 140.2	— 234.2	— 371.0	— 376.4	— 376.2	— 369.1	— 334.3	— 252.3
Temperature (rise)	0	0	— 88.6	— 112.1	— 147.1	— 199.7	— 275.6	— 362.1
Live load	0	0	+ 265.8	+ 309.2	+ 376.7	+ 452.7	+ 478.8	+ 372.2
Impact	0	0	+ 132.9	+ 137.2	+ 150.9	+ 173.2	+ 173.8	+ 127.8
Temperature (fall)	0	0	+ 88.6	+ 112.1	+ 147.1	+ 199.7	+ 275.6	+ 362.1
Maximum	476.3	— 868.7	— 2 665.4	2 554.3	— 2 466.6	2 383.8	— 2 203.0	— 1 868.0
Minimum	— 79.9	— 166.1	230.9	— 97.0	+ 72.2	+ 268.0	+ 416.9	+ 388.4

	D_2'	D_1'	D_1	D_2	D_3	D_4	D_5	D_6
Dead load	+ 123.2	+ 165.7	+ 47.1	+ 35.5	+ 33.5	+ 37.1	+ 34.6	+ 14.9
Live load	+ 395.0	+ 369.0	+ 332.9	+ 308.3	+ 280.6	+ 321.1	+ 473.4	+ 654.8
Impact	+ 215.9	+ 184.5	+ 120.3	+ 106.2	+ 76.9	+ 86.1	+ 143.7	+ 215.4
Temperature (fall.)	0	0	+ 54.6	+ 64.7	+ 79.7	+ 98.2	+ 102.7	+ 50.2
Live load	0	0	— 214.9	— 169.3	— 124.0	— 110.5	— 253.9	— 530.1
Impact	0	0	— 69.4	— 54.6	— 52.9	— 48.7	— 94.1	— 179.0
Temperature (rise)	0	0	— 54.6	— 64.7	— 79.7	— 98.2	— 102.7	— 50.2
Maximum	+ 734.1	+ 719.2	+ 554.9	+ 514.7	+ 470.7	+ 542.5	+ 754.4	+ 935.3
Minimum	+ 123.2	165.7	— 291.8	— 253.1	— 223.1	— 220.3	— 416.1	— 754.4

	V_2'	V_1'	V_0	V_1	V_2	V_3	V_4	V_5	V_6
Dead load	— 120.3	— 156.8	— 252.0	81.1	— 71.1	— 67.7	— 64.0	— 53.7	— 41.8
Live load	445.8	— 465.6	— 613.3	— 392.9	— 346.1	— 312.7	— 331.5	— 376.8	—141.6
Impact	— 243.2	— 232.8	— 204.3	— 133.2	— 94.2	— 75.2	— 95.9	— 115.2	— 73.2
Temperature (fall)	0	0	— 48.8	— 53.2	— 56.9	— 57.4	— 48.8	— 21.6	0
Live load	0	0	+ 166.5	+ 137.7	+ 82.5	+ 47.9	+ 93.8	+ 189.7	0
Impact	0	0	+ 55.4	+ 67.3	+ 40.7	+ 26.1	+ 37.1	+ 69.5	0
Temperature (rise)	0	0	+ 48.8	+ 53.2	+ 56.9	+ 57.4	+ 48.8	+ 21.6	0
Maximum	809.3	— 855.2	1 118.4	— 660.4	— 568.3	— 513.0	— 540.2	— 567.3	—256.6
Minimum	— 120.3	— 156.8	+ 18.7	+ 177.1	+ 109.0	+ 63.7	+ 115.7	+ 227.1	— 41.8

NOTE.—All stresses are expressed in kips, or units of 1 000 lb.

checked at every step of the process. This method of solution, therefore, has a great advantage over any other.

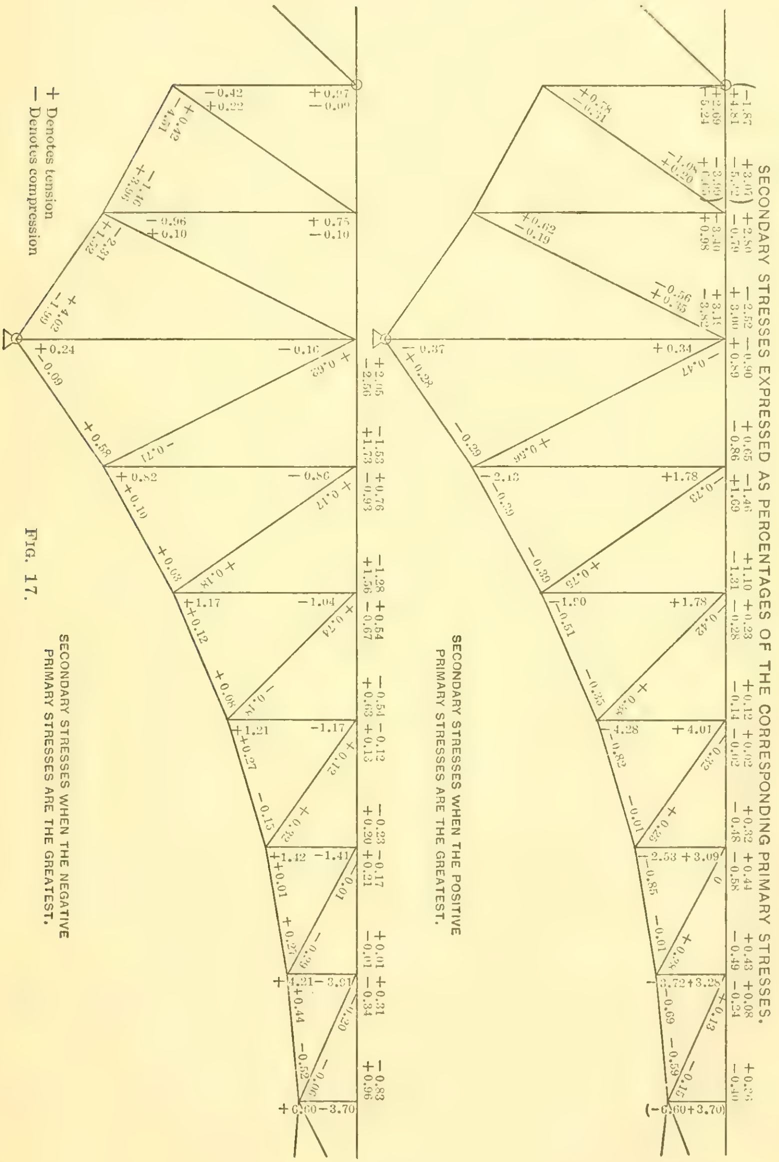
Mr. Mao made an additional simplification of the solution by numbering the joints in the left half of the truss as shown in Fig. 16, Mr. Jacoby. and numbering those in the right half of the truss so that the sum of the numbers for two symmetrical joints is 35, or one more than the total number of joints. By arranging in a table with ϕ_1 to ϕ_{34} at the tops of the columns from left to right, ϕ_{34} to ϕ_1 at the bottom, the numbers of the joints from 1 to 34 on the left side from top to bottom, and the numbers 34 to 1 at the right side, Mr. Mao found that the coefficients were not only symmetrical with respect to a diagonal from the upper left corner to the lower right corner of the table, but also with respect to the horizontal between the numbers 17 and 18. This arrangement saves nearly half the labor by reducing it to 18 equations instead of 34; it requires a table only one-fourth as large as otherwise, so far as coefficients only are concerned; makes a further saving in work in substitutions after some of the values are found, as one substitution gives the coefficients of two unknowns, the sum of the subscripts of which equals 35; it reduces the chance of making errors, as the number of terms to be considered is only half as large as otherwise; gives a more accurate result by avoiding so long a series of substitutions in finding the values of the first few unknowns; and saves time in verifying the check terms.

Fig. 17 gives the secondary stresses in the members of the arch truss, expressed as percentages of the corresponding primary stresses, the loading being such as to cause the maximum and minimum live-load stresses, those for positive primary stresses being shown in the upper part of Fig. 17, and those for negative primary stresses in the lower part. The secondary stresses are for the top and bottom fibers of the upper-chord members, for the top fibers of the diagonals and lower-chord members, and for the outer fibers toward the center of the span in the verticals.

As the members of the cantilever arm have primary stresses due only to one or two live panel loads on the cantilever arm, and the secondary stresses are caused by panel loads over the entire length of the truss, it is necessary to give two sets of percentages for these members. One of these is the percentage of the primary stress for the maximum secondary stress in tension, and the other for that in compression. As U_2' has no primary stress due to vertical loads, the values for its secondary stresses are given as percentages of the primary stress in U_1' as both members have the same composition and section area.

It must be remembered that the values given in Fig. 17 are not all simultaneous, although a few of them are. To study the effect of secondary stresses on the design of any structure, it is most important to know the additional stresses thus produced when the primary stress in each member is either a maximum or a minimum. An examination of these figures shows that in the arch proper the secondary stresses in the upper chord do not exceed 2.56%; in the lower chord 0.85%; in the diagonals 0.75%; and in the verticals, exclusive of V_6, 4.28 per

Mr. Jacoby.


+ Denotes tension
− Denotes compression
SECONDARY STRESSES WHEN THE NEGATIVE PRIMARY STRESSES ARE THE GREATEST.
SECONDARY STRESSES WHEN THE POSITIVE PRIMARY STRESSES ARE THE GREATEST.
+6.60−3.70
(−6.60+3.70)

SECONDARY STRESSES EXPRESSED AS PERCENTAGES OF THE CORRESPONDING PRIMARY STRESSES.

FIG. 17.

Mr. Jacoby.

cent. The vertical, V_6, receives no primary stress except from panel load No. 6, hence two sets of secondary stresses are given, one the greatest positive and the other the greatest negative stress. Both sets really belong to the lower part of Fig. 17, as V_6 has no positive primary stress; but one set is transferred to the upper part of Fig. 17, so as to facilitate comparison with the stresses in other verticals. In the cantilever arm the greatest secondary stress is 4.51%, except in U_2', in which it is 6.65 per cent. In U_2' however, there is no primary stress due to vertical loads, as stated in a previous paragraph.

In computing the secondary stresses, it is always assumed that at any joint the angles between the tangents to the elastic lines of members which meet at that joint remain unchanged. It would be very desirable to have some measurements taken to determine whether this assumption holds true when a truss with riveted joints is deformed under moving loads.

Mr. Ammann.

O. H. Ammann,* M. Am. Soc. C. E. (by letter).†—The analysis of the painstakingly recorded stress measurements, made by Mr. Steinman, may lead the uninitiated reader to overlook the important fact that he has to do with an extremely special case, which may not repeat itself in the history of bridge construction. The author is led to conclusions relative to secondary stresses which, in the writer's opinion, are somewhat too far reaching.

The case is that of the bottom chord of an arch of unusual proportions. The chord itself has an unusual section in size and shape. The joints of the chord members are unique, and the method of assembling the trusses, their erection, and the method of replacing the drift-pins with rivets—all of which features largely affect the secondary stresses—are so special that it is hardly conceivable how conclusions can be drawn applying to arch trusses as a type, and even to bridge structures in general. Furthermore, only the dead-load stresses have been investigated.

This is in no way meant to lessen the value of the measurements or the presentation of the results; on the contrary, if the conclusions drawn by the author are taken to apply strictly to the case under investigation, or to very similar cases, they are infinitely more valuable than if generalized.

It may not be amiss to state here briefly the development of this investigation, with which the writer has been in intimate touch since its inception.

When Mr. Lindenthal first mentioned to the writer his intention of making strain measurements on the Hell Gate Arch, the simple object to be attained was to determine in how far the stresses in the statically indeterminate structure would agree with those calculated.

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* South Amboy, N. J.

† Received by the Secretary, April 8th, 1918.

Mr. Ammann.

Incidentally, the actual bending stresses due to the rigid joints were to be obtained. This naturally referred to the live-load stresses in the completed statically indeterminate two-hinged arch, because, up to that time, no measurements of dead-load stresses were known to have been made, and it was questionable whether any of the existing instruments would be suitable for that purpose.

After preliminary investigation, however, the measurement of dead-load stresses was found to be feasible. In view of the fact that such stresses form the greater portion of the total stresses, the programme was enlarged to embrace, not only the final dead-load stresses, but also those at the various erection stages. The derivation of the actual secondary stresses from those measured was a secondary development.

It was realized, however, that to carry this programme through completely for the two arch trusses would require an excessive sacrifice of time and expense. It was decided, therefore, to confine the measurements to a number of bottom chord members, in view of their preponderant importance and unusual features. Even the programme as carried out involved considerable expenditure, and Mr. Lindenthal cannot be given too much credit for having taken this burden on his own shoulders for the sake of scientific research.

The important facts established beyond question by the investigation are the following:

1.—The measurement of dead-load stresses is feasible, and, for practicable purposes, gives sufficiently close results, provided the stresses are large enough so that the personal factor and other disturbing elements incidental to the measurements become comparatively negligible.

The measurements made are a fair check on the final stress condition from dead load in the bottom chord of the Hell Gate Arch.

2.—The secondary stresses are measurable, but their complete determination, and particularly that of the effect of the various influences, such as method of erection, type of joints, method of replacing drift-pins by rivets, etc., requires far more numerous measurements than have been feasible without undue cost in the case of such a large structure as the Hell Gate Bridge. For this reason only hypothetical conclusions can be drawn from these measurements as to the magnitude of secondary stresses in arch trusses and bridge structures in general.

The measurements have corroborated the expectation that the secondary stresses in the bottom chords of the Hell Gate Bridge are negligible, that is, are more than covered by the margin of safety of the primary stresses.

3.—The measurements have proved the expected favorable action of the three-face joints of the bottom chord, with regard to avoiding dangerous edge pressures and reducing the secondary stresses.

Mr. Ammann.

One important object has not been accomplished, namely, the determination of the actual stresses in the statically indeterminate structure. The dead-load stresses are statically determinate—at least, very nearly so—because such stresses, superimposed after the trusses were converted from two-hinged to three-hinged arches, are very small. In the writer's opinion, it is highly desirable that the measurements be continued so as to embrace the statically indeterminate live-load stresses. They would furnish valuable additional information. As the expense for such further investigation is too heavy for an individual engineer, it should be carried out either by the United States Bureau of Standards or by an Engineering Society in co-operation with the railroad.

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PAPERS AND DISCUSSIONS

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CONSTRUCTION PROBLEMS OF THE MANHATTAN-BRONX, AND LEXINGTON AVENUE SUBWAY JUNCTION AND QUEENSBOROUGH TUNNEL CONNECTIONS

Discussion.*

By C. V. V. Powers, M. Am. Soc. C. E.

C. V. V. Powers,† M. Am. Soc. C. E.—In regard to Mr. Quimby's question concerning the change in plan by which the water-proofing (six-ply fabric laid in hot coal-tar pitch) to be applied to the extrados of the arch was omitted, it appears to the speaker that the answer is very simple—it was not feasible to put in such water-proofing. Mr. Powers.

In 1901 or 1902, in the early days of the construction of the first New York Subway, a short section of tunnel arch was water-proofed with three-ply felt laid in hot asphalt, which experiment came directly under the speaker's observation. This trial section was on Broadway near 157th Street, at, and for a few feet north of, the south portal of the "Fort George Tunnel", the subway being a two-track structure. According to the plans, the concrete of the side-walls and of the arch for a height of 18 in. above the springing line was carried solid to rock; above that point the space between the extrados of the arch and the rock was to be filled with dry stone packing.

The centers being set for concreting a section of arch, about 24 ft. long, the concrete of the arch itself was carried up for a height of about 2½ or 3 ft. on each side and for the full length of the section under construction, using back-forms to conform to the extrados of the arch. Work was then discontinued long enough to allow this

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* Discussion of the paper by George Perrine, M. Am. Soc. C. E., continued from February, 1918, *Proceedings*.

† New York City.

Mr. Powers. concrete to set sufficiently to permit the back-forms to be removed. The surface, where necessary, was then smoothed over with cement mortar, which was allowed to dry. After this the water-proofers took their turn, laying the 3-ply water-proofing in hot asphalt on the portion of the arch just concreted, and for the length of the 24-ft. section, leaving also loose laps—about 8 in. to a foot in width—to be carried under the next lift of water-proofing. Incidentally, it was difficult to protect these laps from injury by the men working over them on the subsequent operations.

The back-forms were then set up again so as to provide for the 3 or 4 in. of "protective" concrete to be placed over the water-proofing, and, therefore, another delay occurred while this concrete was setting and becoming hard enough to resist damage during the placing of the stone packing. After this the stone packing was placed carefully by hand and carried as high as possible.

The foregoing operation was repeated again and again, carrying the concrete, water-proofing, etc., up step by step in heights of some 2½ to 3 ft., until the arch was completed. The height of each individual operation varied according to the room available for the men laying the dry packing to work in, but it is the speaker's recollection that, at the greatest, it would not average more than 3 ft.

As there was an open portal at one end of the 24-ft. section, and the arch had not yet been constructed at the other end, it was possible, though difficult, to water-proof the key of the arch. If both ends had been closed, the speaker knows of no way in which the arch could have been completely water-proofed.

The whole operation of concreting and water-proofing this 24-ft. section of arch, from an elevation 18 in. above the springing line, took—to the best of the speaker's recollection—almost exactly 1 month (due to the necessary delays mentioned and the difficulty of working in cramped quarters), and the operations were carried on under conditions much more favorable than the average, owing to the fact that the section under construction was at a tunnel portal, where there was more room to work and where, especially, there was a good supply of fresh air to diminish the danger from the suffocating fumes of the hot asphalt.

The final decision was very quickly reached, namely, that the result obtained was in no way commensurate with the great expense in time and money, and, further, that it was not feasible for men to work in a tunnel on the water-proofing of an arch, using hot asphalt or coal-tar pitch. The speaker has been unable to find the detailed figures relative to the cost in time and money of doing this piece of work, but it was very high and was considered prohibitive. The experiment was not tried again on subway work, as far as the speaker knows.

Mr. Powers.

It is believed that an informal attempt, on a small scale, was made to water-proof a portion of a tunnel arch, using felt or fabric and a cold water-proofing compound, but this did not give satisfactory results. The water-proofing compound, to be satisfactory, must not only be liquid when cold, but must harden quickly on application and still possess ductility and elasticity to a considerable degree. The speaker does not know of a satisfactory water-proofing compound of this nature, and if there is such, its use would remove only one of the objections to the water-proofing of tunnel arches.

The speaker has had some experience in endeavoring to prevent leakage through tunnel arches by applying a finish on the inside face. Something can frequently be accomplished in that way, but the good results are largely due to a liberal application of "elbow grease" in troweling the surface. It would be far better to apply the same amount of energy on the extrados of the arch, making the concrete on that surface as dense as possible.

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DETERMINATION OF THE DUTY OF WATER BY ANALYTICAL EXPERIMENT

Discussion.*

By Messrs. J. C. Van Reigersberg Versluys and W. L. Rockwell.

J. C. Van Reigersberg Versluys,† Esq.—The subject treated in this paper is of great interest to Java, the country from which the speaker has just come. Mr. Versluys.

Java, one of the larger islands of the Netherlands East Indies, has a population of about 38 000 000, and the people live almost entirely on rice. The density of population is very great as the island is only about one-third as large as California. The birth rate is very high, and it must be expected that the population will be doubled within the next 40 years.

The area planted with rice amounts to about 4 000 000 acres, of which, 2 500 000 acres are irrigated. The average yield of irrigated fields is about 1 000 lb. of eatable rice per acre. All rice is grown on small farms, most of them of from 1 to 2 acres. The rice farmer is a light-hearted, easily satisfied man, who does not work hard, but brings up his family on $60 a year. Of course, this cannot go on, for as civilization advances, the cost of living will continue to rise—the American moving pictures, for instance, have become a necessity in the larger cities.

As almost all the virgin soil is now in use, the Netherlands Government has been induced to undertake extensive investigations with reference to the possibilities of increasing the rice crop in accordance

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* This discussion (of the paper by W. C. Hammatt, M. Am. Soc. C. E., published in February, 1918, *Proceedings,* and presented at the meeting of March 20th, 1918), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Member of the Royal Institute of Engineers, The Hague, The Netherlands.

Mr. Versluys. with the needs of the people. Of course, as the best and most easily irrigated holdings were taken up long ago, the main proposition now is to make the best use of what is still left, and improve the existing systems. The average yield of non-irrigated farm lands is from 50 to 55% of those which are irrigated.

Artificial fertilizers have been tested; they increase the output considerably, but have proved too expensive. The natural fertilizers are in the soil itself, which is generally volcanic. Irrigation helps to supply nitrogen, but phosphorus is the most important element in rice.

Many questions dealt with by Mr. Hammatt are also of the greatest importance in Java. There is not enough water to provide all the later irrigation systems with the conservative quantity of from 20 to 30 in. per year. The latest conclusion arrived at is that the duty of the water cannot be dealt with separately from local geological conditions.

The speaker regrets very much not being able to go further into details, but he has no notes with him to which he can refer.

Mr. Rockwell. W. L. Rockwell,* M. Am. Soc. C. E. (by letter).†—In the field of irrigation engineering the economic duty of water, a subject regarding which comparatively little is known, is of prime importance. In Texas this study has been progressing for more than 3 years, and has included the application of water to cultivated and uncultivated fields, with and without crops, and daily sampling at intervals of from 5 to 30 days, to depths of from 6 to 12 in., both before and after irrigation. During the same periods, an investigation of the evaporation from water and soil surfaces has been conducted. The many and various details are made as comprehensive, and the work is done as accurately, as conditions will permit.

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* San Antonio, Tex.

† Received by the Secretary, April 8th, 1918.

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DISCUSSION ON FINAL REPORT OF THE SPECIAL COMMITTEE ON STEEL COLUMNS AND STRUTS*

By Edward Godfrey, M. Am. Soc. C. E.

Edward Godfrey,† M. Am. Soc. C. E. (by letter).‡—The Final Report of this Committee contains some very valuable data, and deserves the study of all structural engineers. It has long been evident to thoughtful engineers that columns, as commonly designed, are far from having the alleged factor of safety of four which they are so commonly said to have. It has also been evident that there is no warrant in fact for the unit stress, used in tension members, to be applied also in compression members, even though there is a reduction for slenderness.

Mr. Godfrey.

On the face of the results of these tests one striking fact is the small difference between the values for the strength of columns of 50 and 120 radii in length. At first, this would appear to upset formulas and ideas on the relative strengths of short and slender columns. However, correct interpretation of the results brings these tests into harmony with both theory and practice. In other words, correct column theory is not proved to be unreliable, and good practice is not proved to be unsafe; though the fact is that, for indiscriminate designing, a lower unit ought to be used in the column formula.

The three ratios of slenderness used for most of these tests are 50, 85, and 120; but it is not pointed out that these ratios contemplate lengths which are between perfectly fixed ends. It is true that the

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* Continued from March, 1918, *Proceedings*.

† Pittsburgh, Pa.

‡ Received by the Secretary, March 8th, 1918.

Mr. Godfrey. column formula in general use in America—the straight-line formula—is applied without any reference to the rigidity of the ends; but it is also true that examples of truly fixed-ended columns are so rare as to be considered negligible. Columns which butt squarely on a masonry base are fixed-ended and correspond, at one end only, to the columns of these tests. Practically all other compression members of any size in structures may be considered either continuous or pin-ended at the ends, but few are really fixed-ended.

The real length of these test columns, considered as pin-ended, that is translated into practice, is just half of that shown in the Committee's report. The ratios of slenderness are then 25, 42.5, and 60, instead of 50, 85, and 120. The significance of this distinction is seen when a line is plotted representing the ordinary straight-line formula and is compared with the Committee's results of tests after correcting them for slenderness ratio.

The writer has deduced* a purely theoretical column formula which, although it is very complex, gives a locus which is almost identical with the straight-line formula in the range of practical column ratios as used in structural work. The one assumption on which the derivation of this formula is based is that the column is imperfect, and that the imperfection exhibits itself in the deviation of the column from a straight line by an amount of $\frac{1}{300}$ of the length. The formula shows the direct load per square inch which will give an extreme fiber stress on the assumed imperfect column of 16 000 lb. per sq. in.; and this load is found to agree, almost exactly, with $16\,000 - 70\,\frac{l}{r}$ up to the ratios of slender columns.

The average elastic limit of short pieces in compression is not far from 32 000 lb. per sq. in., as shown by the Committee's report. If now, the values of the straight-line formula or the writer's formula are doubled (on the assumption that the factor of safety is two), and if the line is plotted on the Committee's plate LXI, correcting the ratios of slenderness to just half of those shown, the line will traverse right through the dense portion of that plate, where the greater number of test results lie. Furthermore, the shape of this line agrees pretty closely with the shape of the various lines for the individual column groups. This would not be the case with the false ratios given on Plate LXI.

Engineers have long recognized that when the elastic strength of a column has been reached, or has been exceeded by a small amount, it is only a matter of time or the repetition of the same load, until the column fails. The same is true of tension members, though the time and the repetition of stress need to be greater. Chains are commonly used for loads, which give fiber stresses that exceed the elastic limit of the steel; and they commonly fail under the treatment, unless they are annealed in order to restore the weakened metal. Mr. Godfrey.

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* In his book, "Steel Designing."

These tests do not give surprising results, nor results out of harmony with theory, when that theory recognizes that a column is an imperfect member and one in which the imperfection intensifies the destructive effect of loading near the elastic limit. A tension member which is bowed will be partly straightened out under high load, and thus the effect of this imperfection, in adding bending strains, is diminished.

The real factor of safety of a tension member subject to a stress of 16 000 lb. per sq. in. is not much greater than two, for the real elastic limit of ordinary structural steel is not much greater than 32 000 lb. per sq. in. The real factor of safety of a compression member having a stress of $16\,000 - 70\,\frac{l}{r}$ per square inch would be about two, with proper design and metal which is properly rolled, that is, worked down enough to refine and harden it. Because of uncertainties of design and of the quality of the material, however the writer believes that a value lower than 16 000 should be used in the straight-line formula. He believes that $15\,000 - 65\,\frac{l}{r}$ would be a good formula for compression members.

The writer has no apprehension as to the safety of columns designed by the ordinary straight-line formula, when the structures are properly designed, and when they are not overloaded, for he believes that a factor of safety of two is sufficient when the ultimate limit of strength on which this factor is based is an elastic ultimate, and not an ultimate found by speedy loading and rupturing of a member which would fail under much less load if given time.

The Euler load, with a factor of safety of five, is used by European designers. This is an absurdity, for the reason that where the Euler formula has practical application, namely, in slender columns, clear outside of the range of good structural design, no factor of safety of five is needed. There are long wooden derrick booms, being used every day, which have a factor of safety of less than two, based on the Euler formula. The use of the Euler formula for short columns is worse than a guess. At 60 radii that formula shows an ultimate unit stress of 80 000 lb. The Committee's tests show 19 200 to 31 100. At 25 radii the Euler formula shows an ultimate strength of 460 000 lb. per sq. in. No comparison is needed. What meaning could a factor of safety of five have where the ultimate strength shown in the formula bears no relation whatever to the real ultimate strength of the column? The saving feature of European specifications is the upper limit, which, the writer believes, is about 14 000 lb. per sq. in.

Mr. Godfrey. Cause for apprehension, backed by the results of these tests, lies in common methods of design, which frequently ignore eccentric strains, and in the overloading of structures.

The report* of the Committee on Iron and Steel Structures of the American Railway Engineering Association, makes certain recommendations. The report states:

"Unit strains in tension to the extent of 26 000 lb. in structural open-hearth steel and 22 000 lb. in wrought iron will not, in themselves, be sufficient justification for suspending traffic or condemning the structures."

Again it is stated:

"That means if you cut down speeds you can run heavier overloads. It would mean practically taking a 60-ft. girder span at full speed on an overload of about 71 per cent., while at slow speed the overload would be something like 122 per cent."

These ideas are again set forth in Vol. 15 of the *Proceedings* of that Association. It is further stated that "we know from numerous tests and long experience" that properly designed bridges in good condition will safely withstand an overload of 50% without any traffic or speed regulation, and if speed is regulated, an occasional overload of 100 per cent. Further:

"An E-50 A. R. E. Assoc. Specification bridge is a good and economical type with sufficient strength to carry safely, in regular unrestricted service, the heaviest locomotives that can be safely operated without a possible complete revision of present standard clearances."

Now, the relative impact between low speeds and high speeds is something that nobody knows anything about. Some tests have shown less impact for a high speed than a lower one. Impact is caused by roughness of track and lack of balance of driving wheels. If the compression members of a bridge were loaded from 50 to 100% above the ordinary units, where were the factors of safety?

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* *Proceedings*, Am. Ry. Eng. Assoc., Vol. 9.

MEMOIRS OF DECEASED MEMBERS

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

CHARLES LEE CRANDALL, M. Am. Soc. C. E.*

DIED AUGUST 25TH, 1917.

Charles Lee Crandall was born on a farm near Bridgewater, N. Y., on July 20th, 1850. He prepared for college at Whitestown Seminary, Whitestown, N. Y. At the opening of Cornell University his father purchased a farm at Ithaca, N. Y., the seat of that institution, and moved there to educate his children. This was ever afterward Mr. Crandall's home. He entered Cornell as a freshman in 1868, and was graduated in Civil Engineering with the class of 1872, the first four-year class.

After two years of professional practice in geodetic and railroad work, on returning to Cornell for advanced study, he was induced by Professor Fuertes, then head of the department of Civil Engineering, to act as Assistant in teaching, while pursuing his advanced work; and at that time these two men were the entire instructing force in that department.

On August 20th, 1878, Professor Crandall married Miss Myra G. Robbins, of Bridgewater, N. Y., who survives him. Their home life was ever ideal, and their mutual devotion complete. To the "boys" of the College of Civil Engineering their home was a refuge to which they could turn, and return, for advice, for inspiration, and for substantial aid.

Professor Crandall's first teaching was in descriptive geometry. One of the writers was of his first class, and his recollection remains yet most keen of that earnest, honest, modest face. He was more the elder brother than the professor. In our boy parlance we pronounced him "all right", that first term, and have loved him ever since. As a teacher of field work there has never been his equal. His students have proved this in their life work, especially when first leaving his instruction. In those early days each professor was obliged to teach many subjects. Professor Crandall's principal work was in geodesy and railroads, but he taught all field work throughout the student's training.

In 1875 he was made Assistant Professor. In 1876 he took his degree of Master of Civil Engineering, and in 1891 was appointed Associate Professor. He was advanced to the position of full Professor in 1895, and from 1902 to 1906 was Professor in Charge of the College of Civil Engineering. In 1915, having reached the age of retirement, he was made Professor Emeritus.

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* Memoir prepared by the following Committee: Willard Beahan and James H. Edwards, Members, Am. Soc. C. E., and Irving P. Church, Assoc. Am. Soc. C. E.

The following is from an obituary notice of Professor Crandall:*

> "Professor Crandall retained a warm, almost parental, interest in the graduates of the College of Civil Engineering. Through a correspondence bureau, which he conducted for many years, he obtained professional employment for many of these men. He kept the alumni records of the college, which were a model of accuracy and completeness. The Cornell Society of Civil Engineers gave a dinner in his honor in New York City in January, 1916, and established the Charles Lee Crandall Prize in the College of Civil Engineering, besides having his portrait painted, which was presented to the University in June, 1916."

Professor Crandall's authorship of technical books embraces a number of works, on a variety of subjects, prepared for the use of his students. His well-known "Text-Book on Geodesy and Least Squares" was published in 1907, and "Tables for the Computation of Railway and Other Earthwork" first appeared in 1886, reaching a fifth edition in 1916. He also prepared "Notes on Descriptive Geometry" and "Notes on Shades, Shadows, and Perspective". The "Transition Curve" was first published in 1893, a second edition in 1899, and was incorporated as a special chapter in the "Field Book for Railroad Surveying", of which Professors Crandall and Barnes were joint authors. "Railroad Construction", also by these two men jointly, was published in 1913. In addition to these books, Professor Crandall contributed many articles to engineering periodicals.

The following is taken from an article† by F. A. Barnes, Assoc. M. Am. Soc. C. E., Professor Crandall's colleague in the College of Civil Engineering at Cornell:

> "Professor Crandall was a member of the honorary scientific society, Sigma Xi, since 1887, and of the honorary society of Tau Beta Pi since the formation of a chapter at Cornell a few years ago. He was also a member of the Civil Engineering Society, Semaphore, and of the Zodiac Fraternity."
>
> "As a member of many engineering and scientific societies and other organizations, Professor Crandall took an active interest in their work. * * * He was a member of the Society for the Promotion of Engineering Education from its foundation in 1893, served as its President in 1906, and had since been on its Council as a Past-President, *ex officio*. At the time of his death he was also one of its representatives on the Joint Committee on Engineering Education."
>
> "But perhaps his best and most extensive committee work was on the Committee on Iron and Steel Structures of the American Railway Engineering Association, on which he had served since he joined the Association in 1901, a year or two after its foundation. Since

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* *Cornell Alumni News*, September, 1917, p. 479.

† *Cornell Civil Engineer*, October, 1917, pp. 1–8.

1907 he, with Professor F. E. Turneaure, Dean of the College of Engineering of the University of Wisconsin, and others, had been investigating the question of impact on railroad bridges. Several summer trips had been made for the purpose of securing experimental data, and plans had already been made for another in September, 1917. The data already obtained had been worked up, and a new impact formula based on the results had been devised."

"Professor Crandall was ever mindful of his civic responsibilities, and, because of his intimate knowledge of the city, obtained through his long term of service as City Engineer, was often called upon by the authorities for advice. He had served on the Sewer Commission, was a member of the committee appointed to revise the charter a few years ago, and was serving a term as Commissioner of Public Works at the time of his death."

The following paragraph forms a portion of the resolutions adopted by the Cornell University Faculty, in June, 1915, on the occasion of Professor Crandall's retirement from teaching:

"But what was probably Professor Crandall's greatest usefulness was the result of his high unselfish character. His whole life had been given to the devoted service of his associates and of his students. Graduates of the College of Civil Engineering have no memories that do not include a feeling of affection and thankfulness to Professor Crandall. Of kindly disposition and practical sound sense, sympathetic in his intercourse with students, quiet and modest in manner, but with strong convictions as to truth and justice in any matter brought before him, and always ready to sacrifice personal interests in following the dictates of duty, Professor Crandall had won the warm esteem of all who had come within the circle of his influence during his two score years of service at Cornell."

Professor Crandall was elected a Junior of the American Society of Civil Engineers on June 7th, 1876, and a Member on October 5th, 1892.

WILLIAM HAGUE, Assoc. M. Am. Soc. C. E.*

Died January 2d, 1918.

William Hague, First Lieutenant, 116th Regiment of Engineers, American Expeditionary Force, died in active service, of pneumonia, on January 2d, 1918, at the Red Cross Hospital, in Paris, France.

William Hague, the only son of James D. Hague, a very distinguished mining engineer, and Mary Ward (Foote) Hague, of Guilford, Conn., was born in Orange, N. J., on March 31st, 1882. He attended Milton Academy, at Milton, Mass., and was graduated from Harvard University in the class of 1904, taking a post-graduate course in geology and mining.

---

* Memoir prepared by Arthur DeWint Foote, M. Am. Soc. C. E.

On leaving Harvard, Mr. Hague went to work as a surveyor's helper in the mines of the Copper Queen Company, at Bisbee, Ariz., but was soon engaged as Assistant on the construction work of the Copper Queen smelting plant, at Douglas. In the latter part of 1905, he was transferred to the Geological Department of the Company and continued in that work until May, 1906. The summer of 1906 was spent in surveying and prospecting lands in the vicinity of the Calumet and Hecla Mines, in which his father was interested. In the fall, he returned as Assistant on the construction of the Douglas Plant of the Copper Queen Company, and remained there for more than a year. During the winter of 1908, he was traveling and studying, increasing his experience and making careful notes of interesting mines and machinery, and working occasionally. For two months, he was Night Boss in the Cyanide Plant of the Guanajuato Consolidated Mine, but his main purpose was the acquirement of knowledge and experience.

A case of rather complicated appendicitis kept Mr. Hague from work during most of 1908, but, in September, after the death of his father, he was elected Managing Director of the North Star Mines Company. As his father had been President of this Company and had operated the mines successfully for more than twenty-five years, Mr. Hague was his natural successor. During 1909 and 1910, however, he was engaged in geological work in Bisbee, Ariz., for the Copper Queen Company. He also examined all the principal copper mines of Nevada and Arizona, and his notebooks of his observations of the "Porphyry Coppers" are wonders of intelligent detail, arranged in such order and clearness that any engineer might profit by them.

In 1911, Mr. Hague was Assistant to Mr. J. R. Finlay in the appraisal of copper mines for the State of Michigan. Since 1910, when he married Elizabeth Stone, of Milton, Mass., he had resided in Grass Valley, or rather at the North Star Mine. His insatiable thirst for knowledge, however, would not allow him rest from the search, and he studied the mines of the Mother Lode to the south, and of Sierra and Plumas to the north, filling his notebooks as usual with details and maps for future use. He was not only a student of mines, but a great reader of history from his youth, and he constantly acquired the general engineering knowledge obtainable from books, societies, and periodicals. In order that he might broaden his knowledge of engineering, he became a member of the American Institute of Mining Engineers, the Mining and Metallurgical Society, and other technical associations. He was also a member of the Harvard Club, the Engineers Club, and the Downtown Association of New York.

Mr. Hague early recognized the results that would inevitably come from Germany's action in Belgium and on the sea, and prepared himself by going to Plattsburgh in 1916 to learn the trade of war. After earnest work there, he obtained a commission as First Lieutenant in the Engineers Reserve Corps, and was called into service soon after the declaration of war: first at the Presidio; thence to Vancouver Barracks, American Lake, Charlotte, Mineola, and France.

Trained to order and system, and loving them, Lieut. Hague strove for months to bring method and direction into the chaos of the new training camps and teach uncouth boys to be men and soldiers—detailed drudgery of the most wearing kind to his orderly mind. He never failed for a moment in the work, though it undoubtedly weakened him in health, so that when attacked by illness he lived only a few days.

As a brilliant editor has written:

"Military preparation is inevitably attended by some loss of life. In our case, this time, it has been comparatively low. But every faithful soldier, every zealous officer who has died in camp or in transport has given his life as truly to win the war as though he died in actual engagement with the enemy. Whoever has dedicated himself to the war has bargained to give his life whenever it shall be demanded of him. Whether or when the summons will come he cannot tell, but whenever it does come, be it by pneumonia or other camp disease, or by drowning in transport, or by death from wounds at the front, it is equally a case of dedication fulfilled and sacrifice accepted for the great cause that beckons to us all."

Young, with a wife and son, a goodly fortune, a worthy position in his profession, everything to make life worth living, and living that life worthily and happily, William Hague carefully planned and deliberately worked to give it all as the simple duty of citizenship.

Mr. Hague was elected an Associate Member of the American Society of Civil Engineers, on October 4th, 1910.

PAPERS IN THIS NUMBER

"CONSTRUCTION METHODS USED IN BUILDING THE LOWER RESERVOIR DAM OF THE BALMORHEA PROJECT." VERNON L. SULLIVAN. (To be presented May 15th, 1918.)

PAPERS AND DISCUSSIONS CURRENT IN PROCEEDINGS

Final Report of the Special Committee on Concrete and Reinforced Concrete........Dec., 1916
Discussion...Feb., Mar., Apr., May, Aug., Sept., Oct., 1917, Jan., Feb., 1918

"Cement Joints for Cast-Iron Water Mains." CLARK H. SHAW........Mar., 1917
Discussion........May, Aug., "

"Modern Practice in Wood Stave Pipe Design and Suggestions for Standard Specifications." J. F. PARTRIDGE........Apr., "
Discussion........Aug., Sept., Oct., "

"Obstruction of Bridge Piers to the Flow of Water." FLOYD A. NAGLER...May, "
Discussion. (Author's closure.)...Sept., Nov., 1917, Jan., Feb., Apr., 1918

"The Three 15-Cubic Yard Dipper-Dredges, *Gamboa*, *Paraiso*, and *Cascadas*, as Supplied and Used on the Panama Canal." RAY W. BERDEAU........Aug., 1917
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"Air Tanks on Pipe Lines." MINTON M. WARREN........Aug., "
Discussion. (Author's closure.)........Oct., Nov., Dec., 1917, Apr., 1918

Progress Report of the Special Committee to Codify Present Practice on the Bearing Value of Soils for Foundations, etc........Aug., 1917
Discussion........Nov., "

"Detention Reservoirs with Spillway Outlets as an Agency in Flood Control." H. M. CHITTENDEN........Sept., "
Discussion........Nov., Dec., 1917, Jan., Feb., 1918

"A Phenomenal Land Slide—Supplement." D. D. CLARKE........Sept., 1917
Discussion........Jan., 1918

"The Subsidence of Muck and Peat Soils in Southern Louisiana and Florida." CHARLES W. OKEY........Sept., 1917
Discussion. (Author's closure.)....Nov., Dec., 1917, Jan., Feb., Apr., 1918

"A Brief Review of Trigonometrical Mathematical Tables, and a Contemplation of the Specifications for Trigonometrical Tables for General Use." VIRGIL A. EBERLY........Oct., 1917
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"The Hell Gate Arch Bridge and Approaches of the New York Connecting Railroad Over the East River in New York City." O. H. AMMANN...Oct., 1917
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"Stress Measurements on the Hell Gate Arch Bridge." D. B. STEINMAN...Oct., 1917
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"Construction Problems of the Manhattan-Bronx, and Lexington Avenue Subway Junction and Queensborough Tunnel Connections." GEORGE PERRINE........Nov., 1917
Discussion........Jan., Feb., Apr., 1918

"The Activities of the American Society of Civil Engineers During the Past Twenty-five Years." CHAS. WARREN HUNT........Dec., 1917
Discussion........Mar., 1918

"Ice Diversion, Hydraulic Models, and Hydraulic Similarity." BENJAMIN F. GROAT........Dec., 1917
Discussion........Feb., Mar., 1918

"Manhattan Elevated Railway Improvements." F. W. GARDINER and S. JOHANNESSON........Dec., 1917
Discussion........Mar., 1918

"Final Report of the Special Committee on Materials for Road Construction, and on Standards for Their Test and Use........Dec., 1917
Discussion........Feb., 1918

Final Report of the Special Committee on Steel Columns and Struts........Dec., 1917
Discussion........Feb., Mar., Apr., 1918

Progress Report of the Special Committee on the Regulation of Water Rights. Dec., 1917
Discussion........Feb., 1918

"Verification of the Bazin Weir Formula by Hydro-Chemical Gaugings." FLOYD A. NAGLER........Jan., "
Discussion........Mar., "

Progress Report of the Special Committee to Report on Stresses in Railroad Track........Jan., "

"Determination of the Duty of Water by Analytical Experiment." W. C. HAMMATT........Feb., "
Discussion........Apr., "

"The Economics of Steel Arch Bridges." J. A. L. WADDELL. (To be presented May 1st, 1918.)........Mar., "

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"CONSTRUCTION METHODS USED IN BUILDING THE LOWER RESERVOIR DAM OF THE BALMORHEA PROJECT." Vernon L. Sullivan. (To be presented May 15th, 1918.)

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PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XLIV—No. 5

AMERICAN
SOCIETY OF
CIVIL
ENGINEERS
FOUNDED
1852

May, 1918

Published at the Headquarters of the Society, 33 West Thirty-ninth Street, New York,
the Fourth Wednesday of each Month, except June and July.

Copyrighted 1918, by the American Society of Civil Engineers.
Entered as Second-Class Matter at the New York City Post Office, December 15th, 1896.
Subscription, $8 per annum.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852)

VOL. XLIV—No. 5

MAY, 1918

Edited by the Secretary, under the direction of the Committee on Publications.

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American Society of Civil Engineers

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TO CODIFY PRESENT PRACTICE ON THE BEARING VALUE OF SOILS FOR FOUNDATIONS, ETC.: Robert A. Cummings, Edwin Duryea, E. G. Haines, Allen Hazen, James C. Meem, Walter J. Douglas.

ON THE REGULATION OF WATER RIGHTS: F. H. Newell, W. C. Hoad, John H. Lewis.

TO REPORT ON STRESSES IN RAILROAD TRACK: A. N. Talbot, A. S. Baldwin, G. H. Bremner, John Brunner, W. J. Burton, Charles S. Churchill, W. C. Cushing, Robert W. Hunt, George W. Kittredge, Paul M. LaBach, C. G. E. Larsson, G. J. Ray, Albert F. Reichmann, H. R. Safford, F. E. Turneaure, J. E. Willoughby.

◆

The Reading Room of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

HEADQUARTERS OF THE SOCIETY—33 WEST THIRTY-NINTH STREET, NEW YORK.

TELEPHONE NUMBER......................4600 Vanderbilt.
CABLE ADDRESS........................"Ceas, New York."

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* Elected Director April 16th, 1918, to fill the vacancy caused by the resignation of George W. Goethals.

Vol. XLIV. MAY, 1918. No. 5

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

This Society is not responsible for any statement made or opinion expressed in its publications.

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MINUTES OF MEETINGS

OF THE SOCIETY

April 17th, 1918.—This evening was devoted to a meeting of the John Fritz Medal Board of Award for the public presentation of that medal to J. Waldo Smith, M. Am. Soc. C. E., for "achievement as Engineer in providing the City of New York with a supply of water."

Col. John J. Carty, M. Am. Soc. C. E., Past-President, Am. Inst. E. E., and Chairman of the John Fritz Medal Board of Award, presided, and an account of the addresses is given on another page.*

May 1st, 1918.—The meeting was called to order at 8.30 P. M.; Director Samuel T. Wagner in the chair; Chas. Warren Hunt, Secretary; and present, also, 76 members and 6 guests.

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* See p. 476.

The minutes of the meetings of March 20th and April 3d, 1918, were approved as printed in *Proceedings* for April, 1918.

A paper by J. A. L. Waddell, M. Am. Soc. C. E., entitled "The Economics of Steel Arch Bridges" was presented by the author and illustrated with lantern slides.

The paper was discussed by Messrs. T. Kennard Thomson, Charles E. Fowler, H. P. Van Cleve, Samuel T. Wagner, and the author, Messrs. Thomson and Fowler illustrating their remarks with lantern slides.

A communication on the subject from Paul A. Blackwell, Assoc. M. Am. Soc. C. E., was read by title only, on account of the lateness of the hour.

The Secretary announced the election of the following candidates on April 16th, 1918:

As Members

Charles Henry Blackman, Anchorage, Ky.
Edward Abraham Byrne, New York City
Samuel Northrup Castle, New York City
Charles Homer Clark, Pittsburgh, Pa.
George Conrad Habermeyer, Champaign, Ill.
Frank Washburn Jennings, Columbus, Ohio
Howard Eugene Moses, Harrisburg, Pa.
Robert Logan Pearson, Providence, R. I.
James Charles Pinney, Jr., Milwaukee, Wis.
George William Schusler, Pittsburgh, Pa.
Charles George Shafer, Pitman, N. J.
William Wesley Varney, Baltimore, Md.
Sherman Melville Woodward, Iowa City, Iowa

As Associate Members

Kingsley Parkhurst Arnoll, Washington, D. C.
Howard Paul Bayly, Richmond, Va.
Allan Souther Beale, Brooklyn, N. Y.
Edward Michael Brennan, Santo Domingo, Dominican Republic
Robert Andrew Caughey, State College, Pa.
Hazleton Mirkil Chadwick, Valier, Mont.
Herbert Charles Oliver Clarke, Washington, D. C.
Clarence Alonzo Coburn, Hong Kong, China
Nelson Martin Collier, Hastings, Nebr.
Charles Eldridge Davis, Spokane, Wash.
Curt Henry Eiffert, Dayton, Ohio
Lawrence Machemer Fisher, Harrisburg, Pa.
George Mason Garen, Stillwater, Minn.

Paul Charles Gauger, St. Paul, Minn.
Paul Leo Grady, Topeka, Kans.
Alexander Monro Grier, Wilmington, Del.
George Lockwood Hawkins, Elizabeth, N. J.
John Norcom Hendrickson, Ojai, Cal.
Albert Keller Hohl, Philadelphia, Pa.
Philip Zell Horton, Peoria, Ill.
Morton Walker Huttenloch, Montclair, N. J.
Henry H. Hyman, Miami, Fla.
Samuel Louis Kone, Tampico, Mexico
Luther Clyne Lashmet, Kansas City, Mo.
Clarence Victor Milholland, Parkersburg, W. Va.
John Ripley Monaghan, Elmhurst, N. Y.
Julian Montgomery, Austin, Tex.
James Archibald Moore, Camp Doniphan, Fort Sill, Okla.
Robert Bradley Nichols, Washington, D. C.
Ralph Mason Roberg, Raymond, Wash.
Walter Ellsworth Rowe, Columbia, S. C.
William Augustus Smith, Tuckahoe, N. Y.
Charles Samuel Stevenson, Eckman, W. Va.
Paul McGowan Tebbs, Harrisburg, Pa.
Arnold Hines Vanderhoof, New Brunswick, N. J.
Alexander Charles Waller, Fort Sheridan, Ill.
Ernest Welden, Eldora, Iowa
James Baker Woodson, Fresno, Cal.
Frank Dennett Yost, Philadelphia, Pa.

As Juniors

William Eustace Chandler, Boston, Mass.
Frederick William Carl Ebeling, New York City
James Perkins Ewin, New Orleans, La.
John James Hurley, Boston, Mass.
Thomas Richard King, Los Angeles, Cal.
Albert Lossen Lane, Jackson, Tenn.
James Gray McKelvey, St. Louis, Mo.
Herbert Martin Palmer, New York City
Edward Alexander Reinke, Santa Clara, Cal.

The Secretary announced the transfer of the following candidates on April 16th and 17th, 1918:

From Associate Member to Member

David Barnard Steinman, New York City
Rupert Kennedy Stockwell, Salt Lake City, Utah
Samuel Arnold Greeley, Chicago, Ill.
Henry Schwing Kleinschmidt, Salt Lake City, Utah

Charles MacDonald, White Plains, N. Y.
Robert Reimann, Relay, Md.
William Beauvais Smith, Jr., New Orleans, La.
William Lawrie Stevenson, Philadelphia, Pa.
Bertrand Hinman Wait, New York City
Barclay White, Philadelphia, Pa.

From Associate to Member

Albert Henry Bromley, Jr., Canton, Ohio

From Associate to Associate Member

Elmer Earl Moots, Continental, Ariz.
John Milton Ritchie, Washington, D. C.

From Junior to Associate Member

Ralph Tisdale Alger, Cleveland, Ohio
Harold William Bloemker, Philadelphia, Pa.
Alec Edward Brook, Sheffield, England
Herbert Arthur Davies, Roanoke, Va.
Ralph Burrows Everett, Syracuse, N. Y.
Ralph Edward Goodwin, New York City
Thomas Hughes Holmes, Camp Grant, Ill.
John Raymond Lapham, Washington, D. C.
Samuel Macelroy Lowrey, Baltimore, Md.
Harold Gilbert McGee, Toledo, Ohio
Cyril Ernest Davis Marshall, Garden City, N. Y.
William Menke, Kingston, N. Y.
Frederick Herman Munkelt, Washington, D. C.
Samuel Isaiah Sacks, Philadelphia, Pa.
Julius Herschel Serra, Brooklyn, N. Y.
Harold Clinton Seward, Brooklyn, N. Y.
Philip Joseph Walsh, Charleston, W. Va.

The Secretary announced the following deaths:

Thomas Aspinwall, of Boston, Mass., elected Member, May 2d, 1888; died March 2d, 1918.

James Aubrey Davenport, of Roanoke, Va., elected Member, April 5th, 1905; died March 15th, 1918.

William Huggins, of Rio de Janeiro, Brazil, elected Member, February 7th, 1906; died February 21st, 1918.

Clarence Booth Lamont, of Seattle, Wash., elected Associate Member, May 4th, 1909; Member, June 24th, 1914; died March 21st, 1918.

Jesse Lowe, of Beardstown, Ill., elected Member, October 2d, 1895; died April 17th, 1918.

William McKelvey Marple, of Scranton, Pa., elected Member, June 4th, 1890; died March 20th, 1918.

Marshall Pope Robertson, of New Orleans, La., elected Associate Member, March 5th, 1902; Member, September 4th, 1906; died November, 1917.

Edward McKim Hagar, of New York City, elected Associate Member, February 6th, 1901; died January 18th, 1918.

Clark Wallace Thompson, of Cascade Locks, Ore., elected Junior, March 5th, 1890; Associate Member, July 3d, 1895; died March 16th, 1918.

Adjourned.

OF THE BOARD OF DIRECTION

(Abstract)

April 16th, 1918.—The Board met at 10 a. m.; President Talbot in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Alvord, Darling, Davis, Duryea, Fay, Flinn, Hawgood, Herschel, Hill, Humphreys, A. M. Hunt, Kittredge, Khuen, Lewis, Noble, Pegram, Rights, Swain, Tillson, Wagner, Wall, and Webster.

Mr. Alvord, Chairman of the Committee on Special Committees, presented a Report.*

Certain resolutions adopted by the Executive Committee on November 1st, 1917, and subsequently approved by the Board of Direction, having been forwarded to the various Local Associations of Members, with request that they consider them, and the Utah Association, the Colorado Association, and the Northwestern Association of Members having taken action on the matter, the whole question was considered by the Board, and the following resolution was adopted:

"*Resolved:* That while disclaiming any desire to control individual opinion or its expression, or any protest of Local Associations of the Society, made to the Board, against any of its acts, the Board of Direction disapproves and condemns the action of the Utah, Colorado, and Northwestern Local Associations in making public their official action which protested against the action of this Board."†

The following resolution with regard to remission of annual dues of members of the Society engaged in the prosecution of the war was adopted:

"*Resolved:* That the Board of Direction of the American Society of Civil Engineers, recognizing the sacrifices made by the members of the Society who have entered the service of the United States Government, or its Allies, to aid in the prosecution of the war, authorizes the Executive Committee to exempt members in the Military, Naval or auxiliary services of the United States, or its Allies, from the payment of annual dues, and to make such decisions and rules as may be deemed necessary to carry out the spirit of this resolution."

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* See page 460.

† A full statement of the action of the Executive Committee of the Board and the three Local Associations, and other Associations, in this matter, will be found on pages 461–465.

Rules for Admission of Additional Societies to Engineering Council, which have been approved by the Council after conference with the Committee of this Board appointed for the purpose, were presented and adopted.*

A Report of the Committee of the Southern California Association on the Relation of the Society to its Local Associations, etc., together with a letter from W. E. Belknap, M. Am. Soc. C. E., also a member of that Committee, was presented. The Report of the Committee had been approved by the Association. These documents were forwarded for presentation to the Board, and subsequently, if the Board so orders, for publication in *Proceedings*. The entire matter was ordered printed in *Proceedings*.†

An invitation from the American Association of Engineers to this Society to send Delegates to the Annual Meeting of that Association, on May 14th, 1918, at which certain referenda will come up for discussion, as well as other questions pertaining to the welfare of the Engineering Profession, was presented, and the following resolution was adopted:

"*Resolved:* That the Board of Direction of the American Society of Civil Engineers declines the invitation to send Delegates to the meeting of the American Association of Engineers, as it feels that matters of the character which are indicated by the referenda accompanying the invitation should be handled by and through the Engineering Council, which is an organization representing the leading National Engineering Societies."

The action of the Executive Committee in abandoning the Collations at the Regular Meetings of the Society, as a war economy, was approved, and it was ordered that the Collations be abandoned until further notice.

On the recommendation of the Secretary, the following resolutions were adopted:

"*Resolved:* That regular business meetings of the Society be held, as required by the Constitution, on the first Wednesday of each month except during July and August, and that at these meetings, in addition to the regular business, professional papers previously published shall be presented for discussion.

"*Resolved:* That, at the meetings held on the third Wednesday of the month, the programme of papers, addresses, or discussions, shall be placed in the hands of a Committee of seven resident members to be appointed by the Executive Committee and to be known as the New York Meetings Committee, this Committee to be charged with the entire responsibility for the conduct of these meetings."

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* See page 473.

† See page 465.

The resignation of Maj.-Gen. George W. Goethals as a member of the Board of Direction representing District No. 1 was taken up. Gen. Goethals presented his resignation on account of the fact that he had moved to Washington and re-entered the service of the Government and could not attend to the duties of the position.

The resignation of Gen. Goethals was accepted with regret.

On the unanimous nomination of nine resident members present (not including the Secretary), Edwin J. Fort was unanimously elected to fill the vacancy caused by the resignation of Gen. Goethals as one of the Directors representing District No. 1.

Mr. Fort was notified of his election and later attended the meeting of the Board.

The resignation of Louis C. Hill as a member of the Nominating Committee representing District No. 11, on account of inability to attend a meeting of the Committee, was presented, and accepted with regret. Mr. Hawgood stated that the members of the District would like to see Mr. W. K. Barnard appointed to fill the vacancy caused by Mr. Hill's resignation. The Board appointed Mr. Barnard.

The President was authorized to appoint a Committee of three to evolve a plan by which the Directors in each District, or the Secretary, or other officer of the Society, should visit from time to time the various Local Associations.

The resignations of 1 Member, 4 Associate Members, and 3 Juniors, were accepted.

Ballots for membership were canvassed, resulting in the election of 13 Members, 39 Associate Members, 9 Juniors, and the transfer of 16 Juniors to the grade of Associate Member.

Ten Associate Members were transferred to the grade of Member, 1 Associate to the grade of Member, and 2 Associates to the grade of Associate Member.

Applications were considered and other routine business transacted.

Adjourned.

April 17th, 1918.—The Board re-convened at 3.50 P. M.; President Talbot in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Alvord, Davis, Duryea, Hawgood, Herschel, Humphreys, A. M. Hunt, Khuen, Kittredge, Lewis, Noble, Pegram, Rights, and Webster.

A report from the Membership Committee was received and acted upon.

Adjourned.

SOCIETY ITEMS OF INTEREST

Exemption from Payment of Dues of Members in War Service

The following Resolution was passed by the Board of Direction at its meeting on April 16th, 1918:

"*Resolved:* That the Board of Direction of the American Society of Civil Engineers, recognizing the sacrifices made by the members of the Society who have entered the service of the United States Government, or its Allies, to aid in the prosecution of the war, authorizes the Executive Committee to exempt members in the Military, Naval or auxiliary services of the United States, or its Allies, from the payment of annual dues, and to make such decisions and rules as may be deemed necessary to carry out the spirit of this resolution."

Report of the Committee on Special Committees

"To the Board of Direction,
"American Society of Civil Engineers:

"The Committee on Special Committees (who have had referred to it, by the prior Committee of last year, the request of certain members on the Pacific Coast for the appointment of a Committee on Creosoted Wood Stave Pipe) beg to report that the prior Committee of last year have turned over to them a very considerable amount of correspondence which had been accumulated, containing inquiries of all the prominent engineers interested in the subject as to their opinion of the necessity of such a Committee, and their replies thereto.

"Your Committee have been through this correspondence carefully, and find a considerable difference of opinion as to the necessity of such a Committee, particularly at this time.

"There also appears to be some doubt expressed as to whether such an investigation would be entirely free from criticism, owing to the fact that an investigation of that kind has a distinctly commercial side as well as being a problem of purely scientific character, but your Committee feel that the matter which has the greatest weight with them at the present time is the general policy of the Society's investigations, which it is felt ought to be limited, during the war, to those subjects which are of special value to the Government and the country in winning the war.

"After conference and deliberation, your Committee are unanimously of the opinion that it is inexpedient at this time to appoint a Special Committee on the Investigation of Creosoted Wood Stave Pipe.

"Respectfully submitted,

"John W. Alvord, *Chairman*,
Edwin Duryea,
Geo. W. Tillson."

"Chicago, Ill.,
"Mar. 15th, 1918.

Excess Profits Tax on Income of Engineers

At the meeting of the Board of Direction, April 16th, 1918, a Committee specially appointed by the President for that purpose presented the following statement to the Board.

On November 1st, 1917, the following resolutions were adopted by the Executive Committee. These resolutions were subsequently reported to the Board of Direction and approved, and forwarded to all our Local Associations:

"*Whereas,* Congress has passed an act known as the War Revenue Act of 1917; and

"*Whereas,* Under Section 200 of said act it is stated 'The terms "trade" and "business" include professions and occupations'; and

"*Whereas,* Section 209 of said act states 'That in the case of a trade or business having no invested capital or not more than a nominal capital there shall be levied, assessed, collected, and paid, in addition to the taxes under existing law and under this act, in lieu of the tax imposed by section two hundred and one, a tax equivalent to eight per centum of the net income of such trade or business, in excess of the following deductions: in the case of a domestic corporation, $3 000, and in the case of a domestic partnership, or a citizen or resident of the United States, $6 000, in the case of all other trades or business, no deduction'; and

"*Whereas,* In most cases the professional man's earnings constitute his sole income, from which must be derived the capital which will yield a competency for himself and family, and inasmuch as these earnings are subject to the established income tax, including supertaxes, this same income should not be taxed further as if it were excess profits, when as a matter of fact it is not excess profits; and

"*Whereas,* It is discriminatory and unjust to tax earned income at a higher rate than unearned income; and

"*Whereas,* In other countries where incomes are taxed the tax is heavier on unearned than on earned incomes, thus encouraging industry and thrift;

"*Resolved,* That in the opinion of the Executive Committee of the Board of Direction of the American Society of Civil Engineers, the provisions in Sections 200 and 209, hereinabove quoted, should be repealed because they are discriminatory and unjust.

"*Resolved,* That the Secretary be and he is hereby directed to publish the above in *Proceedings,* and to send copies to the other National Societies and to the various Associations of Members, urging similar action. Also, to forward copies to Hon. F. M. Simmons, Chairman of the Committee on Finance of the Senate, and Hon. Claude Kitchin, Chairman of the Ways and Means Committee of the House, requesting the repeal of the above-mentioned provisions at the next session of Congress. Also, to urge each member of the Society to act individually by communicating directly with his representatives in Congress along similar lines."

Resolutions disagreeing with the action of the Executive Committee have been received from the Utah Association of Members, from the Colorado Association of Members, and from the Northwestern Association of Members. All these resolutions condemn the action of the Executive Committee and of the Board as being untimely during the present war, approve the War Revenue Measure which the resolution of the Executive Committee criticized, and urge that the Congress of the United States be not annoyed and handicapped in its efforts to provide means to carry on the war.

The resolutions of the Utah Association state:

(1) That members of the Utah Association brought this same principle to the attention of the parent Society under date of January 29th, 1917, asking that the matter be made the subject of a discussion by the members of the Society through the columns of the "*Transactions.*"

(2) That the Executive Committee tabled the said suggestions at a time when such discussion would have been perfectly proper.

As a matter of fact, it does not appear that the first of these statements is correct. The letter in question from Messrs. Charles F. Brown and H. S. Kleinschmidt stated their proposition as follows:

"Through a proposed State Income Tax now before the Legislature of the State of Utah we have interested ourselves in the general question of the justice in taxing the incomes of professional men, and particularly those of engineers, at the same rate and on the same basis as the taxes on incomes derived from property investments and paid by business men."

The letter further states:

"If these questions can be made the subject of discussion by the members of the Society through additional communications on our part and personal discussions of the Central Society meetings we shall be glad to participate in such discussions."

The remainder of the letter is an argument as to the difference between investments made by the professional man and those made by the business man, and the conclusion arrived at is that these two gentlemen are convinced that the rate of taxation on the incomes of professional men should not be as high as the rate of taxation on the incomes from business investments.

This it will be seen is not at all the question which was taken up by the Executive Committee and subsequently approved by the Board of Direction.

The resolutions of the Utah Association, of which Mr. H. S. Kleinschmidt is Secretary-Treasurer (Mr. Kleinschmidt being one of those who wrote the original letter which was tabled by the Board) were ordered sent to each Local Association of Members, and to each Senator and Representative from Utah in Congress.

The Colorado Association at a meeting held December 8th, 1917, in a resolution which quoted the resolutions adopted by the Executive

Committee and the letter of transmittal from the Secretary written by order of the Executive Committee, makes the following statements:

(1) That the Association hopes and believes that these resolutions do not voice the sentiments of the majority of American Engineers. That the statement made that the taxes therein referred to are "discriminatory and unjust" is unwarranted, that the Association regards the action of the Executive Committee as unpatriotic and highly improper, and strongly disapproves of said action.

(2) That with nearly six hundred members of the Society in the military service of the United States, it is peculiarly unbecoming and ungrateful in those of us who stay at home to protest our part in the financial burden.

The following resolutions were adopted by the Northwestern Association of Members of the American Society of Civil Engineers at a meeting held January 18th, 1918.

"*Whereas:* The Executive Committee of the Board of Direction, of the American Society of Civil Engineers, at a meeting held November 1st, 1917, adopted resolutions asking for the repeal of Sections 200 and 209 of the War Revenue Act of 1917, providing for the taxing of incomes from trade and business and including professions and occupations under the above terms, on the grounds that they are discriminatory and unjust, and,

"*Whereas:* Our Country is now at war with unusually heavy burdens resting on the Government and every class of citizens is feeling the effects of added taxation to help in prosecuting the war,

"Now, Therefore, Be It *Resolved:* That the Northwestern Association of Members of the American Society of Civil Engineers regards the action of the Executive Committee in adopting the resolutions referred to as untimely during the present war, and,

"Be It Further *Resolved:* That this Association approves the war revenue measure, and urges that the Congress of the United States be not annoyed and handicapped in its efforts to provide means to carry on the war, and,

"Be It Further *Resolved:* That copies of these resolutions be sent to the Board of Direction of the American Society of Civil Engineers, to each Local Association of Members of that Society and to each Senator and Representative from Minnesota in the Congress of the United States."

It would seem as if these Associations of Members had misunderstood the action taken by the Executive Committee, and subsequently confirmed by the Board, and it is submitted that the statement made by the Executive Committee that the excess-profits tax is discriminatory and unjust, and the action in adopting the resolution and sending it to Congress, were neither "unpatriotic" nor "highly improper." The view expressed was practically a universal one.

The Society of Naval Architects and Marine Engineers, to which the action was also forwarded, stated under date of November 27th, 1917, that its Council had decided to take the same action, and adopted the same resolution under date of November 14th, 1917.

A letter was also received from the Secretary of the American Chemical Society heartily approving of the action taken, and stating that he felt sure that society would favor the action.

The minutes of the Duluth Association of Members of the Society, at its November 19th, 1917, meeting, state as follows:

"The resolutions adopted by the Board of Direction relative to the 8% supertax on incomes of professional men, under the new revenue law, were read, and, on motion, duly seconded, it was decided to endorse the resolution and protest the tax as unjust, the protest to be signed by the President and Secretary and sent to representatives of the State of Minnesota in the Senate and House of Representatives and that, in addition, all members of the Association be urged to make personal remonstrances."

At the St. Louis Association of Members meeting of November 26th, 1917:

"A letter from Chas. Warren Hunt, Secretary of the Society, relative to the Resolution of the Executive Committee of the Board of Direction on the War Revenue Act of 1917, together with the Resolution, was read, and the Act was discussed.

"On motion, duly seconded, the Secretary was instructed to write to the Board of Direction, advising it that the Association would do all in its power to have the Act amended."

At the Cleveland Association of Members meeting of January 5th, 1918:

"The resolution of the Executive Committee of the Board of Direction of the Society relative to the War Revenue Act of 1917, was read, and the subject was discussed by Messrs. Leffler, Ellms, Ritchie, Spencer, and F. C. Osborn.

"On motion, duly seconded, the resolution was approved as the action of the Association, and copies were ordered sent to the Senators and Representatives in Congress from Ohio.

"On motion, duly seconded, it was also decided to instruct the Legislative Committee to confer with other professional bodies requesting similar action."

At the February 23d, 1918, meeting:

"The Secretary read communications from the Colorado and Utah Associations in reference to the War Income Tax. Mr. B. R. Leffler reported for the Legislative Committee that he had communicated with all the associations of professional men in Cleveland relative to the subject and that the local chapter of the American Institute of Architects had agreed to co-operate to secure a repeal of Sections 200 and 209 of the law."

At the Portland, Ore., Association of Members meeting of January 11th, 1918:

"The resolution of the Executive Committee of the Board of Direction of the Society, relative to the War Revenue Act of 1917, was presented, and it was decided to address communications to the Oregon Senators and Representatives as suggested and that individual members of the Association should use their personal influence to get the clause affecting engineers and professional men repealed or amended."

The Board adopted the following resolution on April 16th, 1918:

"***Resolved:*** **That while disclaiming any desire to control individual opinion or its expression, or any protest of Local Associations of the Society, made to the Board, against any of its acts, the Board of Direction disapproves and condemns the action of the Utah, Colorado, and Northwestern Local Associations in making public their official action which protested against the action of this Board.**"

Local Associations

The following report (together with the accompanying letter from W. E. Belknap, M. Am. Soc. C. E.) has been received from the Southern California Association, and is here printed for the information of the membership. The original "Report of a Committee, appointed by the Board of Direction, on the Relations of Local Associations of the American Society of Civil Engineers to that Society, to other Engineering Organizations, and Engineers, and to the Public", is printed in *Proceedings* for May, 1917. The action of the Baltimore, Cleveland, Seattle, and Colorado Associations is recorded in *Proceedings* for October, 1917.

The Southern California Association, at its meeting of December 12th, 1917, adopted the report of Messrs. George G. Anderson and Samuel Storrow.

"Dec. 12, 1917.

"TO THE SOUTHERN CALIFORNIA ASSOCIATION
OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS,
Los Angeles, California.

"GENTLEMEN.—Since submitting its report of August 6th, 1917, endorsing the report of Messrs. Bontecou, McDonald and Jonah on the 'Relations of Local Associations of the American Society of Civil Engineers to that Society, to other Engineering Organizations, and Engineers, and to the Public', as printed in the *Proceedings* of May, 1917, your Committee appointed to consider that report have been instructed to make further report and recommendations on various suggestions submitted by other Local Associations and now submit the following for your consideration, as a basis for discussion of radical changes in the policies of the Parent Society.

"It is the conclusion of your Committee that the modifications of and additions to the Bontecou report suggested by its discussion by the

Seattle Association, of August 27th, 1917, lead most directly to such changes in the administration of the Parent Society as will make it most truly national in character and in influence, and that the principles enunciated in these modifications should receive your endorsement. The elaboration of the details of the changes in the Constitution which will become necessary in the event of the adoption of such alterations, merits further and careful consideration, to which all the members of the Society should devote their earnest attention.

"Your Committee herewith submit each suggestion, with brief comments thereon, with the purpose and hope of concentrating attention and eliciting discussion.

"*First,* that:

"'One or more delegates from each local section be sent to the Annual Meeting, with expenses paid by the Society, and that definite responsibility in the conduct of the business of the Society be imposed upon these delegates.'

"It is clear that the adoption of the suggestions entails, as Mr. Jacobs, President of the Seattle Association, points out in his letter to Secretary Hunt of September 17th, 1917, a radical recasting of Article VIII of the Constitution of the Parent Society. It would appear to be advisable to limit the 'Business Meetings' of such delegated organization to, one a year, it would be necessary to define clearly the character of 'business' to be transacted only by such delegated organization, and just as clearly that general attendance at such Annual Meetings should be encouraged, although the 'business' would be conducted only by the appointed delegates. The number of delegates should be fixed on the basis of proportional representation, and that, not necessarily upon the membership of the Local Associations, but upon the membership in the Parent Society in the districts into which the distribution is now, or may later be subdivided.

"*Second,* that:

"'All applications for membership be considered by the Local Section having jurisdiction before being acted upon by the Board of Direction.'

"The Bontecou report recommends that the Local Association 'should investigate carefully the qualifications of any candidate for admission to the Society, about whom the Board of Direction desires information, and make an official report at the request of the Secretary of the Society.'

"The Seattle Association's suggestion goes much farther, making it a function of the Local Association to consider such applications, without request, and, practically, in advance of action by the Board of Direction. It is highly probable that, in considering applications at the present time, the Board of Direction, if in doubt, does not take final action without consultation with the officers of the Local Association. The suggestion of the Seattle Association merely makes the probable custom an official requirement, the advisability of which cannot be doubted.

"In connection with this suggestion, attention may be directed to the paragraph 'Ethics', in the Bontecou report, in which the following provision is made:

" 'Charges made by any member of the Society that any member of the Section has violated this code should be promptly investigated by a committee of the Section, and its findings officially reported to the Board of Direction.'

"As details, consideration should be given to the means of creating such committee and to the propriety of its findings being submitted, first, to the Local Association for approval, before being reported to the Board of Direction.

"*Third,* that:

" 'Professional papers be first presented to a local section except those that may be selected for annual meetings or conventions.'

"Such provision, latterly, has become the practice; its advantages are patent.

"*Fourth,* that:

" 'A sufficient proportion of the annual dues be remitted to the Sections to care for the necessary expenses.'

"The Local Associations already organized have exercised a stimulating influence on the Parent Society, have materially increased its membership by bringing the advantages of association closer to the younger members of the profession; and the influence of the Local Association is limited by financial ability. The advisability of increasing the dues of membership in Local Associations to more than $3 per annum, in addition to the dues to the Parent Society, is doubtful, and the remission of such an amount, or 20%, from the dues to the Parent Society to the Local Associations, on the basis of their membership, would not embarrass the treasury of the Parent Society, even with the addition of the expenses of delegates to the Annual Meeting. Such provision may affect the distinction between Resident and Non-Resident Members, as the number of the Local Associations increases within the present Resident zone. That distinction is now confined to a limited area, though it comprises one-seventh of the total membership of the Society, and it is not improbable that any loss incurred in resident dues would be offset by the increase of dues from the general increase in membership resulting from the activities of the Local Associations. Uniformity in the dues to the Parent Society is thus foreshadowed, for which, with the increase in the number of Local Associations, there would be justification, if, otherwise, the total amount of dues is sufficient for the financial necessities of the Parent Society, and if the Resident Member is not to be taxed for the advantages of ready access to headquarters, library, and other facilities.

"*Fifth,* that:

" 'The work of headquarters' office be developed along the line of general administration including the appointment and direction of standing committees, issuing the publications and arranging for annual meetings and conventions, with the added responsibility of extending the influence of the Society through Local Sections.'

"Some such limitation is inevitable, if the preceding alterations in general policy are adopted.

"*Sixth,* that:

"'Local Sections shall consist of not less than twenty-five (25) nor more than five hundred (500) members of all grades.'

"The Bontecou report makes the minimum membership in a Local Section 'at least twenty-five members of all grades'. There does not appear to be any good reason for a limitation of the maximum membership, though a study of the geographic limits of the thirteen districts, into which the Society membership is now subdivided, indicates the improbability of any one Local Association reaching a membership of 500.

"Your Committee believes that consideration should be given to the designation 'Section' proposed to be given to the Local Associations, by the Bontecou report. It is desirable that the designation be as descriptive as possible and acceptable to the members.

"Your Committee favors the endorsement of the general principles embodied in the various suggestions made by the Seattle Association.

"GEORGE G. ANDERSON, *Chairman.*
"SAMUEL STORROW."

"DECEMBER 6TH, 1917.

"MR. H. W. DENNIS,
"SECY., SOUTHERN CALIFORNIA ASSOC. OF MEMBERS, AM. SOC. C. E.,
"Los Angeles, Calif.

"MY DEAR MR. DENNIS.—With reference to the discussion on December 12th of the communication from the Seattle Association, I shall not be able to be present, but wish to express briefly some views on the various suggestions in their order as follows:

"*First.*—The business of the Society is already delegated to a Board of Direction, as it should be, and the proposition to create another Board to act at the Annual Meeting or business meetings will either divide responsibility or complicate it. I can see no useful purpose in the suggestion. The Director representing our District will always be fully qualified to express its opinion at the regular meetings of the Board of Direction.

"*Second.*—All applications for membership can now be considered by any Local Section, and acted upon by it, if it is deemed necessary. To make it mandatory that they should be acted upon by Local Sections before going before the Society as a whole does not seem to add in any way to the discrimination which should be exercised on applications.

"*Third.*—There seems to be no objection that professional papers be first presented to a Local Association, but there is an objection in this provision being made mandatory.

"*Fourth.*—If the scheme as outlined should be carried out, and a portion of the dues remitted, there is no doubt that the Resident Members of the Society living in District No. 1 would be justified in asking that the excess dues which they pay should be omitted. This would reduce the dues of the Society about $17 000. Fifteen dollars per year does not seem to be any more than compatible with a Society of the character of the Am. Soc. C. E., and it might be well to mention here that there are some 125 subscribers to the publications of the Society who pay more than $15 per annum for the privilege of receiving them.

"It would seem to me that the functions of any General Meeting of a large organization cannot be more than to register new sentiments or ideas, and that these must always be digested and developed by the smaller body of Directors who are elected to manage the affairs of the Society. The means of taking a general vote by the whole Society on any subject is already provided for.

"I understand that the meeting of the Society last night was addressed by Mr. Hunt, the Secretary, who gave a very valuable historical outline of its development, and that this will be printed in the December *Proceedings.* It would seem to me to be wise that any discussion on this subject should not be concluded until this address is read over by the members.

"Yours very truly,
"W. E. Belknap."

Engineering Council's Growing Activities

At the regular bi-monthly meeting of Engineering Council on April 18th, 1918, many matters of common concern to engineers, as well as some of public welfare, in which the Profession is interested, were acted upon. There was a large attendance, and representatives from several other bodies appeared before the Council. The procedure for the admission of additional societies to membership in Engineering Council was perfected, and several societies were nominated; important new committees were created, and statements of work done were received from committees previously appointed.

The American Engineering Service has continued busily engaged in responding to requests from the War, Navy, and other departments of the Government, for men for special technical services. Chairman George J. Foran, of this Committee, reported that large numbers of names had been supplied through the co-operation of leading engineering and chemical societies. Special assistance is being given to the Ordnance Department in securing officers to expedite production; to the Navigation Bureau in finding men for the submarine service; to the Signal Corps in procuring special employees for aviation work; and to the Tank Corps in enlisting non-commissioned officers and mechanics. In connection with the last item the Military Engineering Committee of New York has supplied engineering specialists to interview candidates in the rooms of the American Society of Mechanical Engineers and the American Society of Civil Engineers. General arrangements for these interviews were made by Capt. R. C. Stevens, of the Army Tank Corps, through the offices of Engineering Council.

The War Committee of Technical Societies, of which D. W. Brunton is Chairman, has official connections with the War Department as well as with the Naval Consulting Board. Its function is to review the many new inventions and other suggestions constantly being received, and select those worthy of investigation or development by the Navy, War, or other Departments. Being of a confidential nature, the details of the work of this Committee cannot be published.

On the recommendation of the Public Affairs Committee, Charles Whiting Baker, Chairman, a resolution was passed urging the authorities of the engineering schools of the country to direct all their resources to the winning of the war in such ways as relieving from routine duties, as far as practicable, teachers engaged in work for the Government or on other war work, and allowing such teachers the assistance of undergraduate students; by crediting such students for this work, if it can be done properly, by relieving them of prescribed work in their courses of less importance; by offering shops and laboratories for the solution of war problems; and by training undergraduates in the fundamentals of engineering, even at the sacrifice of some specialization on subjects not connected with the war. The Secretary was directed to send copies of this resolution to the technical colleges.

Professor L. P. Breckinridge, Chairman of the Fuel Conservation Committee, reported that matters of importance had been considered for the Fuel Administration and for the Bureau of Mines.

In order to follow up the good work in connection with water-power legislation, begun by Engineering Council, and to be prepared for effective action on other questions arising in the broad field of utilization and conservation of water for municipal supply, power development, irrigation, sewage disposal, and navigation, a new committee, to be known as the Water Conservation Committee, was formed.

Matters concerning the welfare of engineers in the war services of the Government have received hardly more than accidental attention from the engineering societies and, in some instances, none at all, because of the lack of a suitable organization to deal with them. To meet these needs in a broad way, Engineering Council authorized the formation of a Military Aid Committee to deal with activities ranging from supplying the needs of some engineering unit in a training camp or in combatant service to assisting the Government authorities in recruiting special engineering units or utilizing military engineering units on public works after the war.

The question of licensing or registering engineers under State laws was referred to the Public Affairs Committee for study and the organization of a special sub-committee to deal with the subject actively.

Chairman J. Parke Channing, of Engineering Council, announced that the following well-known engineers had accepted appointment on the Patents Committee, created by the Council at its February meeting: Charles A. Terry, Chairman, C. A. P. Turner, Corydon T. Purdy, J. Parke Channing, Horace V. Winchell, Edwin J. Prindle, D. S. Jacobus, and Frank N. Waterman. This Committee will investigate reforms in the United States Patent system and in the use of experts in litigation wherein the validity of patents or other technical matters are involved, co-operating with similar committees of the National Research Council and technical societies.

By invitation, President F. P. Fish of the National Industrial Conference Board presented to Engineering Council, resolutions adopted by the Board at its meetings being held in New York City. These resolutions requested Engineering Council, as the representative of the great engineering societies of the United States, to investigate and publicly express itself as to whether or not the Nation is gaining or losing in industrial efficiency, and what causes, if any, are influencing the condition, and in what manner, broadly, it is believed, industrial efficiency can be further stimulated. These resolutions also urged opposition to proposals under consideration in Congress in connection with appropriation bills to prohibit, diminish, and condemn the payments to public employees, or employees of private establishments under Government control, of any cash reward, premium, or bonus for superior services. Mr. Fish was accompanied by Mr. James A. Emery of the War Labor Board, who presented strong arguments in support of the resolutions. By vote of Engineering Council, the Chairman appointed as a special committee to give this matter immediate attention: Professor George F. Swain, Chairman, E. W. Rice, Jr., Chas. T. Main, Alexander C. Humphreys and Benjamin B. Thayer.

At the request of the War Committee of Technical Societies, an officer who had had extensive experience on the Western Front, explained to the Council the importance of having a suitable proportion of engineers, superintendents, and foremen, who had had practical experience in construction work, properly distributed among the fighting troops in addition to those in the engineering and labor regiments.

The relationship of Engineering Council to local societies received extensive consideration, and will come up for action at a later meeting of the Council.

Action of Engineering Council in Reference to Industrial Efficiency

Engineering Council has appointed the following Committee on Industrial Efficiency: George F. Swain, Chairman, E. W. Rice, Jr., Charles T. Main, Alexander C. Humphreys, and Benjamin B. Thayer.

Owing to the rapidity with which the Army and Navy Appropriation Bills are being considered by Congress, and the fact that these bills contain proposals opposed to well-tried industrial methods for improving efficiency and increasing production in manufacturing plants, the Committee without delay drafted a resolution which was adopted by special action of Engineering Council. The resolution is as follows:

"*Whereas*, the winning of the War imperatively demands highest efficiency and maximum production in every branch of industry, and

"*Whereas,* we are informed that Congress has under consideration in the Naval and Army appropriation bills proposals to prohibit, diminish and condemn the payment to public employees or to employees of private establishments under Government control any cash reward, premium or bonus for superior service, and

"*Whereas,* these methods if applied with due regard to wages, surroundings, health and safety of the employees, will increase efficiency and production, help win the War and preserve our institutions, be it, therefore,

"*Resolved,* that in the opinion of Engineering Council, representing American Society of Civil Engineers, American Institute of Mining Engineers, American Society of Mechanical Engineers, and American Institute of Electrical Engineers, together having 33 000 members, it is vital to the winning of the War that no legislation or other measure should be adopted which may interfere with highest efficiency and maximum production, but that on the contrary every proper means should be taken to increase efficiency and production."

This resolution was telegraphed to the Senate Committee on Naval Affairs and to Charles M. Schwab, Manager of the Emergency Fleet Corporation. It was also sent to the Senate Committee on Military Affairs and to a number of engineers in the home States of the Senators on these two committees, with a request to these engineers that they communicate at once with their Senators.

The objectionable clause in the Appropriation Bills is as follows:

"That no part of the appropriations made in this Act shall be available for the salary or pay of any officer, manager, superintendent, foreman, or other person having charge of the work of any employee of the United States Government while making or causing to be made with a stop-watch or other time-measuring device a time study of any job of any employee between the starting and completion thereof, or of the movements of any such employee while engaged upon such work; nor shall any part of the appropriations made in this Act be available to pay any premiums or bonus or cash reward to any employee in addition to his regular wages, except for suggestions resulting in improvements or economy in the operation of any Government plant."

Engineers, especially those engaged in industrial operations, will readily understand the serious effect which legislation of this kind would have on private plants engaged largely or exclusively on war work under the appropriations carried in these bills. It is most important that such measures should not be enacted.

A careful reading of the third preamble of the resolution adopted by Engineering Council will show that the Council and its Committee fully realize that the best interests of the workmen must be conserved, and its action has no ulterior purpose to the contrary. The earnest desire of Engineering Council is patriotically to promote in every way the largest production and best efficiency of the country's industrial establishments.

On the subject matter of the resolution adopted on April 18th, 1918, by the National Industrial Conference Board, the Committee is now concentrating its attention and making a careful investigation. The resolution is as follows:

"*Whereas,* it is daily becoming more apparent that the winning of the war demands the highest efficiency in every kind of production, and

"*Whereas,* many causes and circumstances have unfortunately operated to obstruct, diminish and even interrupt necessary war production, and there is much information and experience to justify the belief not only that we are in many instances securing less production per unit of time and person than heretofore, but that the country is continuously confronted with proposals to lessen the hours of production without first determining the wisdom of such action, and

"*Whereas,* it seems that manufacturers are not fully alive to the necessity of not only providing the best and most systematic service instruction to new labor but should constantly be endeavoring by every practical means to improve the efficiency of the older force, the plant and themselves, and

"*Whereas,* it appears that Congress has under consideration in the Naval and Army Appropriation bills proposals to prohibit, diminish and condemn the payments to public employees or to employees of private establishments under Government control any cash reward, premium, or bonus for superior service and to forbid time studies, and

"*Whereas,* it appears that the members of the great Engineering Societies of the United States are peculiarly qualified by virtue of their knowledge and experience to express an opinion upon the present efficiency of our production and the most practical means of increasing the productive capacity of both management and men and to call to public attention questionable proposals threatening our efficiency as a nation and therefore our capacity to perform our full duty in this great struggle.

"*Therefore, be it Resolved* that the National Industrial Conference Board respectfully requests the Engineering Societies of the United States to investigate and to publicly express themselves as to whether or not we are losing or gaining in industrial efficiency, and to state what causes, if any, in their opinion, are influencing the condition, and in what manner broadly they believe our industrial efficiency can be further stimulated."

Rules for Admission of Additional Societies to Membership in Engineering Council, Approved February 21st, 1918

1.—The expression "additional society" as used in these rules refers to any society elected to membership in Engineering Council, other than the Founder Societies of United Engineering Society

(American Society of Civil Engineers, American Institute of Mining Engineers, American Society of Mechanical Engineers, and American Institute of Electrical Engineers).

2.—Any representative on Engineering Council shall have the privilege, at any meeting of the Council, of proposing for membership in Engineering Council the name of any national engineering or national technical society, being a society which is national in the scope of its activities and is not by its title identified with any State or municipality, and is devoted to the advancement of the Engineering arts and sciences, such proposal to be in writing setting forth the name and general standing of the society and number of its members.

3.—A proposal for membership, made in accordance with Rule 2, shall be acted upon by Engineering Council at its next regular meeting, and, if favorably acted upon, shall be submitted to the Trustees of United Engineering Society for the purpose of securing the approval of the governing body of each of the four founder societies.

4.—If a proposal be approved as provided in Rule 3, the Secretary of Engineering Council shall then notify the nominee of the desire of the Council to have the proposed society become a member, informing it of the duties and obligations it will incur, of the number of representatives to which it will become entitled on Engineering Council, and of its privileges as a member of the Council.

5.—Upon the receipt by the Secretary of Engineering Council of a written communication from the proposed "additional society", expressing its intention to become a member of Engineering Council, and the payment to the Treasurer of United Engineering Society of the required entrance fee, the said society shall become a member of Engineering Council.

6.—Each "additional society" shall be entitled to name one representative, provided it has not over 2 000 members; if it has more than 2 000, it shall be entitled to name an additional representative for each additional 2 000 members, or any fraction thereof not less than 500; but its total number of representatives shall not exceed 5.

7.—Each "additional society" admitted to membership in Engineering Council shall pay an entrance fee of $250 per representative which it is entitled to have on the Council, and thereafter assessments shall be the same per representative for each Founder and "additional society". United Engineering Society shall not be assessed for its representatives.

8.—Any "additional society" may withdraw from membership in Engineering Council at the end of any calendar year, provided written notice of the intended withdrawal shall have been sent by the society to the Secretary of Engineering Council and all indebtedness of the society to Engineering Council shall have been paid.

9.—In case two-thirds of the representatives on Engineering Council, including at least three representatives of each Founder Society, shall vote in favor of the termination of the membership of any "additional society", such membership shall cease, said vote to be taken by letter-ballot.

10.—These rules may be amended or additional rules adopted by a majority vote of the representatives of the Council, upon the approval of the governing body of each of the four Founder Societies.

Addresses at the Public Presentation of The John Fritz Medal to J. Waldo Smith, M. Am. Soc. C. E.

April 17th, 1918

Col. John J. Carty.—Ladies and Gentlemen: As Chairman of the John Fritz Medal Board of Award, I have the great honor and privilege of presiding at this meeting, which is called for the purpose of presenting the John Fritz Medal to Mr. J. Waldo Smith for his most distinguished services in Civil Engineering, and particularly in connection with the work on the great aqueduct, which has just been completed.

You will hear from the speakers of the evening in most eloquent terms much about Mr. J. Waldo Smith and his wonderful work. I will say just a word about the medal, the award of which is considered the highest honor which can be conferred on an engineer in America. It is not simply a medal given by the members of one society, for it is awarded by a Board composed of the four great National engineering societies of America: The American Society of Civil Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, and the American Institute of Mining Engineers.

In practically all cases the members of the Board of Award are Past-Presidents of those Societies. The names of the most distinguished engineers are rigorously canvassed; and this year the very great honor fell to our colleague.

The medal itself was founded in 1902 in honor of John Fritz, of Bethlehem, Pa. The Board of Award is composed of sixteen men, as I have just described, and the medal has been awarded to men only of the most distinguished achievement and of the very greatest fame. The first award was to Lord Kelvin for his work in cable telegraphy; the next to George Westinghouse; then to Alexander Graham Bell; Thomas Alva Edison; Charles T. Porter; Alfred Noble; Sir William H. White; Robert W. Hunt; John E. Sweet; Dr. James Douglas; Dr. Elihu Thomson; Dr. Henry M. Howe; and now, this evening, the medal is to be presented to J. Waldo Smith.

I will not undertake to say more, but will introduce Mr. Nelson P. Lewis, Vice-President of the American Society of Civil Engineers, and for many years Chief Engineer of the Board of Estimate of the City of New York. Mr. Lewis is an old colleague and fellow-engineer of Mr. Smith, and you will be very glad indeed to hear his words of appreciation.

I have very great pleasure in introducing Mr. Lewis.

Nelson P. Lewis.—Mr. Chairman, and Gentlemen of the Board of Award, Ladies and Gentlemen: The remarks of the Chairman, and the programme of the evening have told us of the origin of the John Fritz Medal in 1902, and the names of the thirteen men on whom it has already been bestowed. They constitute a select roll of honor, and we are here this evening to celebrate the addition of one more name to the list. I esteem it a rare privilege to be permitted to speak for the Engineering Profession in extending our congratulations to the latest recipient of the honor.

Mr. Smith is so well known that an extended review of his professional activities will be unnecessary, but a brief outline of the development of a conspicuously successful hydraulic engineer may not be out of place. It would be difficult to find a better instance of the success which is quite sure to result from persistent devotion to all phases of a particular line of engineering work. It began in his boyhood, when, as a lad of 15, he eagerly availed himself of such opportunities as were afforded to help in the construction of a waterworks system for his home town in New England. It was a very modest plant, consisting of a small reservoir and pumping station, and about 4 miles of pipe. Probably it was the most important improvement the town had undertaken, and he not only tried to make himself generally useful on the work, but made it the subject of his school compositions and essays. That his interest was intelligent and his volunteer work was of real value is shown by the fact that, several years later, when a vacancy occurred, he, though still a boy of 17, was given charge of the operation of the plant, acting as fireman, engineer, and general superintendent of the work.

This experience appears to have brought a realization of the need of a thorough scientific education, and, after two years in charge of these works, he entered the scientific course at the Phillips Andover Academy. Then followed two years of service with a water-power company, where much time was devoted to the measuring of water. His technical education was not yet complete, but was rounded out by the full engineering course at the Massachusetts Institute of Technology, his summer vacations being devoted to practical work with a water-power company.

It has been said that the young graduate of an engineering school is not an engineer, but one who may with practical experience soon become an engineer. This alternation of study and practical application of what he had learned proved an ideal training, and when he received his degree in engineering he was a real engineer, rather than a man who might readily become one through practical experience; and it is not surprising that his progress after graduation was rapid.

In 1890 he became connected with the East Jersey Water Company, and for the next 13 years was engaged in the construction of an extensive system of reservoirs and pipe lines to supply a number of towns in Northern New Jersey, his work here culminating in the design and construction of the filtration plant at Little Falls, which was at the time the largest in the United States.

In 1903 the Aqueduct Commissioners of New York City wanted a chief engineer, and the position was offered to and accepted by Mr. Smith. The large new Croton Dam was then under construction, and the necessity for its prompt completion was believed to be imperative. The work was pushed energetically, and the impounding of water began within the following year. During his incumbency of this office other important parts of the Croton Water Supply were under construction, including the Jerome Park Reservoir, the Muscoot Dam, and the building of roads and bridges, while the plans were prepared and construction was commenced on the Cross River Reservoir.

In 1905 came the opportunity for which Mr. Smith's experience had peculiarly qualified him. The project of the Catskill Water Supply for New York, so persistently and successfully advocated by Mayor McClellan, who fully understood its magnitude and importance, had been finally authorized, and the Commission created by the statute selected Mr. Smith as Chief Engineer. It was a huge undertaking, involving the construction of a great storage reservoir in the Catskills, the enlarging of the Kensico Reservoir, and the building of a large distributing reservoir near the northerly boundary of the city, in addition to an aqueduct nearly 100 miles in length which must cross the Hudson River and other streams.

This work has been described so fully and so frequently that no outline of it will be attempted at this time. Its total cost was estimated to be about $175 000 000, and it was obviously necessary to plan its execution so that the different parts of the work should be completed at such times as would permit the delivery of water at the earliest possible date—first to reinforce the Croton supply and then bring it directly to the city, avoiding heavy carrying charges on portions of the work completed long before they could be used, a too frequent occurrence in projects of this magnitude. The plans and general programme were worked out with this purpose in view.

When first outlined they may have appeared somewhat extravagant. The organization proposed was large and very complete, providing for thorough investigations, the preparation of plans, and orderly construction. It included provision for expert geological study to determine the most advantageous location and the depth of the river crossings, for the architectural as well as the engineering design of the great dams, and the landscape treatment of their surroundings, and many other details which are commonly left to be determined at a later date and too often in a hasty and ill-considered fashion. The wisdom and foresight of the designer, however, were shown to have been amply justified, and it is doubtful if an undertaking comparable with this in scope, in cost, and in difficult engineering problems has been so well synchronized in its various parts and so executed as to render in so short a time the service for which it was designed.

A modern system of water supply lacks most of the spectacular features of those of ancient times, when long aqueducts spanned the valleys—structures which to-day afford striking examples of the engineering and architectural skill of the builders of those periods. Mr. Herschel has pointed out that the skillful engineer will use to the best advantage the materials and facilities at hand. "This is what the Romans did," he says, "not having cast-iron pipes, they builded as best could be done without them, and were we deprived of cast-iron, wrought-iron, and steel pipes, we should to-day be obliged to build water-works pretty much as they built them." This intelligent use of modern materials and facilities has permitted much saving of time and expense, even though it may have involved a loss of the picturesque and spectacular. Our aqueducts are underground, and, except for an occasional stretch of embankment or a cleared right of way, there is little trace of the existence of the life-giving stream of water flowing uninterruptedly from the mountains to the great city—nothing to indicate the difficult engineering problems which had to be solved.

The crossing of the Hudson, for instance, owing to the great depth of the river gorge, presented peculiar difficulties which were solved in a novel and ingenious manner. While the work on the great reservoir in the Catskills and portions of the long aqueduct was getting under way, the most careful study was being devoted to the best location of the river crossing. The narrows between Storm King and Breakneck Mountains appeared most advantageous, provided sound rock were found at a reasonable depth. Borings were made from scows anchored in the river, and the drills were sent down for hundreds of feet, but, before rock suitable for tunneling was found, high winds or collisions by river craft resulted in a loss of the core borings. It was finally decided to sink shafts, about 200 ft. in depth, on each side of the river and to drill holes from the bottom of these shafts, inclined at several angles, and thus decide beyond question at what depth sound rock was sure to be found. In drilling holes 2 000 ft. or more in length, however, it was of the utmost importance to know that their proper inclination to the horizontal was maintained; or, what was the departure from that inclination? To determine this, recourse was had to what has been called a hydrofluoric acid survey, which consisted in the insertion into the borings, at intervals of about 100 ft., of glass tubes containing hydrofluoric acid. After lying there for some 30 min. they were withdrawn, and at the surface of the acid there was etched on the glass a line which showed the inclination to the horizontal at that point, and a profile of the borings could thus be made. This indicated that at a depth of about 1 000 ft. below the river surface, good tunneling rock was to be found. The shafts were accordingly carried to a depth of 1 115 ft. below tide, or 1 125 ft. below hydraulic grade, and the tunnel was driven from each of the shafts at that depth in rock so firm and sound that very little water was encountered.

At the Rondout and Wallkill, borings showed that the glacial gorges were far below the existing beds of these streams, and not directly beneath them. This made it necessary to construct siphons about 4½ miles in length, and at depths considerably below sea level. Then there was the pressure tunnel under Manhattan Island and parts of the Bronx and Brooklyn, passing under the Harlem and East Rivers, and varying from 200 to 750 ft. below the surface. Again, there is the pipe line under the Narrows by which the Catskill supply is delivered to the Silver Lake Reservoir in the Borough of Richmond. And now there is to be added the long tunnel through Shandaken Mountain by which the waters of the Schoharie are to be turned into the Ashokan Reservoir.

All these structures are far beneath the surface, well out of sight, and the difficulties encountered and the skill displayed in their solution can only be appreciated by those who were familiar with the work during its progress, or those who will take the trouble to examine the official plans and reports.

There are still impressive evidences of the skillfulness and thoroughness of the work, but most of them are far from the city, such as the great dams at Ashokan and Kensico, with their simple but admirable treatment, and the very attractive features added by the aerating fountains at each, while the Gilboa Dam on the Schoharie is still to be built. The City of New York, doubtless, will be commended, rather than criticised, for the relatively slight additional expense involved in making these structures dignified and attractive, and worthy of the great city which has carried out this undertaking. The fine highways, which have been built along these reservoirs, and the admirably designed bridges carrying them across the watercourses, contribute in a marked degree to this impression. They are public structures of the City of New York, and, though far beyond its corporate limits, they should be a credit to the city. And yet, it required no small degree of courage to recommend that they should be made attractive as well as simply utilitarian.

The element of time has been referred to as of paramount importance, especially that no vital part of the work should be so delayed as to postpone the use of the system when the other parts were ready for service. Although this was quite obvious, it took rare courage on the part of the Chief Engineer to advise in the most emphatic manner the award of the large contract for the Ashokan Dam to a contracting company, which had already demonstrated its capacity to carry out so large an undertaking quickly and satisfactorily, but whose proposal was 20% higher than the lowest bid, especially when that 20% meant somewhat more than $2 000 000. Yet this was done, and the recommendation was adhered to, notwithstanding the storm of criticism to which he and the commission were subjected in the public press. It is true that such a course would be adopted by a railroad or business corporation, but in this case public funds were involved, and the plea that it was a war measure could not be advanced, and the guardians of the public interests are savagely critical of any suggestion that an additional price be paid to secure prompt performance, even though such a course might result in an ultimate saving, to say nothing of promptly meeting an urgent public need. The recommendations of the Chief Engineer prevailed, and the soundness of his judgment was fully demonstrated by subsequent events.

Great technical skill in design, however, even when coupled with capacity to plan an organization to execute efficiently, may not produce the desired results, in the absence of certain human qualities which stimulate enthusiasm and promote good team work. Fortunately, Mr. Smith possessed these qualities in a conspicuous degree. Not only was the plan of organization admirable, but rare judgment was shown in the selection of the department and division engineers. Under them came a large number of engineers, whom it was necessary to take from civil service eligible lists; but all down the line were to be found the same keen interest and pride in their work which were shown by the chief and his principal assistants. What was it that compelled this keen interest and loyal devotion to the work in hand? It was the feeling that the Chief Engineer had a personal interest in the men as well as in the work. It was the conviction that whatever credit might come from successful performance would not be monopolized by the chief, but would be shared by every man who contributed to that success. If any subordinate engineer was placed in charge of a part of the work involving special difficulty, or in which novel methods were used, there was no prohibition against his talking or writing about it. On the contrary, he was encouraged to do so.

Owing to the great extent and variety of the work, one whose duties were confined to a particular locality or a special problem might have a very hazy idea as to what was going on at other points and an inadequate comprehension of the project as a whole. To overcome these limitations, illustrated talks, descriptive of the work at certain points, were given to groups of men employed on other sections, with the result that every one who cared to acquire a knowledge of the work as a whole was enabled to do so.

But the Chief Engineer of so great an undertaking must deal with many others besides his own engineering staff, and in these relations there is need of the exercise of diplomacy combined with firmness, insistence on rigid enforcement of obligations, coupled with absolute fairness and shrewdness, as well as kindliness. To what degree these qualities were shown will, doubtless, be indicated by another speaker.

And then there is the impression which Mr. Smith has made upon his fellow engineers, the men to whom I have the honor of speaking, men who may not have had any direct connection with the great work with which he has been so closely identified, but who have taken a keen professional interest in it. May I not draw from one of the ingenious methods used in that work, and to which reference has already been made, a very simple illustration? As the acid traced upon the inner surface of the glass tubes inserted in the borings under the Hudson a line which indicated the direction in or the directness with which they were being driven, so, in our association with this master builder, there has been clearly etched upon our consciousness a distinct mark, and that mark has been always a level line—a level head, a warm heart, high ideals, and Yankee shrewdness—a combination as rare as it is admirable.

Of the work of the engineer, Professor Tilden of Johns Hopkins University, in a delightful essay on the "The Romance of Engineering", says: "The dominant note is the spirit of service, the recognition of a public need and a striving to fill it." To-day, as never before, the engineer, with whatever branch of the profession he may be identified, is being afforded an opportunity for service—service to his city, service to his country, service to civilization. On the service flag of the Engineering Profession, indicating the part they are taking in the great struggle for justice and righteousness on which the eyes of the world are now focused, are many thousands of bright, blue stars. Some of them are shining more and more brightly; some are growing pale and dim, and will soon be effaced by clouds, but, higher up on the flag, they will soon be replaced by the glowing, golden stars of sacrifice. Whether blue or gold, they tell the story of devoted service.

Mr. Smith, permit me, on behalf of your fellow engineers, to offer you our heartiest congratulations upon the tribute which is being paid to you to-night. Many honors have lately been bestowed upon you, none of which, we think, will be more highly prized than this. We want to share the gratification which it will bring to you.

And, gentlemen of the Board of Award of the John Fritz Medal, permit me, also on behalf of Mr. Smith's professional friends, to assure you that we believe that your selection of the recipient of the medal for 1918 was a wise one.

The Chairman.—I know that I express the feelings of all present when I say that it is very fortunate that we have chosen Mr. Lewis to deliver this address. As an engineer, I feel very proud that we have one among us who can produce an address with so much literary charm and so worthy of being preserved.

The next speaker will be the Hon. A. T. Clearwater, who will give an expression of appreciation of our Medalist from the standpoint of a public man, a jurist, a lawyer, and a citizen of New York, who has attended, as a member, two of the Constitutional Conventions of this State.

I know that we will all be very greatly edified and interested in hearing the appreciation which will be delivered by Judge Clearwater.

A. T. Clearwater.—Ladies and Gentlemen: I was informed by the Committee of Arrangements that the address of the evening was to be delivered by my friend, Mr. Lewis, and a statement, or rather a résumé, of what he was to say was forwarded to me; but, in writing to me and inviting me to come here, the Committee stated that it was desired to present to the engineers of these various associations a typical Catskill mountaineer; and in looking around in the recesses of the Catskill Mountains for a typical mountaineer, I was selected. So you see, in my person, and venturing into this gilded metropolis, a shy and unwonted visitor from these mountain streams, which have been so successfully dammed—in so many senses dammed—by my distinguished friend, the honored guest of the evening, J. Waldo Smith.

The Committee sent me a brief of what Mr. Lewis would say, and when I looked over the list of the attributes of Mr. Smith to which Mr. Lewis was to devote himself, I saw that there was nothing left for me to talk about except the cutting of the first tooth of Mr. Smith, and an account of his various amatory exploits before he settled down into a sober-minded Benedict.

When I took up the subject of cutting his first tooth, I tried to find the nurse who officiated on that important occasion. I found that she was still so youthful that she was endeavoring to teach the soldiers of France and England to cut a new set of teeth on the Western Front; and when I took up the subject of Mr. Smith's amatory exploits, I was so deluged with information that I gave up the attempt with sorrow, heartbroken to feel that I could not do justice to them.

Now, this is a much more solemn occasion that I had anticipated it would be. In the Catskill Mountains when we decorate a man, we always treat it as a joyous occasion. We do not treat it so solemnly as I find this; and yet, after all, it is a great occasion in a man's life, and a great occasion in the history of these organizations that combine to decorate him and to bestow upon him this medal, the great embellishment of the engineering world. It is a singular coincidence that of the recipients of this medal, I have known but the first and the last. It was my good fortune to know Lord Kelvin, the first recipient, and with him and the Chinese Ambassador to the United States, Dr. Wu Ting Fang, I was at Niagara Falls at the time of Lord

Kelvin's visit there, which was the occasion of the operation of the installation at that place of turbines for the generation of electric energy by falling water. I have seen much water diverted from its natural course since the time I visited Niagara Falls with Lord Kelvin. I have seen much of the water which should be drunk in Ulster County sent down to this thirsty city by the distinguished guest of to-night; and I suppose that we shall be dry in Ulster for generations to come, because of the labors of your guest, which entitle him to this medal of distinction. .

I have known him ever since he dawned above the horizon of the Catskills. I have differed with him upon many, many occasions. I expect to differ with him upon many, many to come. I am utterly unable to recall since I first met him, before the Legislature of the State of New York in 1905, down to this time, the 17th of April, 1918, when we have been able to agree upon a single question.

Therefore, by the philosophy of contradictions, by the law of differences, have I the antipodal attraction, as it were.

I am brought here from my modest home in the mountains, the mountain roads and the mountain streams which are the tributaries of the Esopus, to assist in paying this tribute to him to-night. And yet, notwithstanding these differences, you will be surprised—some of you will be shocked—I know, to hear me say that I have a great admiration for him, an admiration predicated upon his sterling character, his great scientific attainments, the scientific attitude, the intellectual detachment, the desire to be sure, and to be right, which has characterized his conduct as the Chief Engineer of this colossal work.

Even in the Catskills, we do not live the life of the Garden of Eden, and you may be surprised to know that up along the trout brooks there are sources of unhappiness, of discontent, and that some of us are foolish enough to believe that we would be better off if we were in New York, in the thirst, and the dust, and the dirt of this town. I am not one of those. I am content with war rations and undiverted Esopus water. Therefore, it is that I speak with the greater freedom. I have known the members of this Board of Water Supply. I see in this audience my distinguished friend, the Hon. Charles Strauss, who was Chairman of the Board until a few days ago; until, in one of those spasms of economic reform which sometimes possess the souls of good men, he was tempted to resign—a most unwise proceeding, and I fancy a most unhappy proceeding for the taxpayers of New York.

Some of you read the Bible, or have read it, and doubtless remember about the swarms of locusts that descended upon the fields of Egypt. They were as nothing compared to the swarms of engineers which overspread the Catskills. You could count the locusts of Egypt, but you could not count the engineers that came up to the

Catskills to take our water. The chief among them was Mr. Smith, and all the maledictions, all the vindictive ejaculations, were hurled upon his devoted head; and the astonishing thing is that he survived it all, and that he looks so well and so handsome to-night, as he comes here to receive the crowning reward of his labors.

The characteristics of Mr. Smith's efforts have been exactness, accuracy, and veracity. Now, those are virtues which we treasure in the mountains. I am a stranger in this town. I read the newspapers; I fancy, as I read them, and the editorial comments, that you do not cultivate the great virtues of accuracy, and industry, and veracity here. Perhaps that is an error; but, when Smith came up to Ulster, those were the virtues that characterized his conduct. That is why I am here, because it was the only thing we had in common.

They mapped out, under his tutelage, in the mountains, the property of every person whose holdings were condemned for this vast reservoir, covering miles. I think, 13 villages, 27 churches, 42 school houses, 36 cemeteries, all sorts of factories, all sorts of industries; and it was part of my duty, as a Catskill Mountain lawyer, to investigate the accuracy of those surveys, because surveying in the mountains is one of the great mysteries. To you engineers, surveying is as simple as A-B-C, but to us, in the mountains, there was a constant belief at first that the engineers, in making their surveys, were always allotting to the property owner less land than he had, always trying to "turn sharp corners", and surveying into their maps property which they did not intend to pay for.

Well, after I had investigated several hundred, made under the management of Mr. Smith—of the several thousand that were made—and had failed to find a single inaccuracy in any one of the surveys, I came to the conclusion that after all, when his job was over, he might be entitled to the John Fritz Medal.

And another thing.. You know, up in the country, we have more time to discuss the problems of statecraft than you have here. You live so hurried a life; you are so devoted to pleasure; you give such scant attention to the higher ideals of existence, that you are unaware how essential tact and diplomacy are in dealings with your fellow-men, and particularly in dealings with your fellow-women. This man is a wonderful diplomat. I know of no man in the circle of my acquaintance who would be a better representative at the court of an oriental despot than our friend Mr. Smith. He has that singular faculty of never seeming to insist upon his own way, and of getting his own way every time that he starts out to get it. Now, is not that the first quality of a diplomat, and has it not been one of the crowning features of his career?

And he has attained it, without—as Machiavelli, as Rochefoucauld, as Voltaire, and as Rousseau have all said—he has managed to attain it without lying; and you will remember that they all said that a diplomat was a man sent abroad to lie for the benefit of his country. We have been able to rely upon what he said—I will not say that he said very much. I think I might say that a subdued reticence was the great characteristic of his conversation; but what he did say was reliable.

Something has been said, not by me, but my friend Mr. Lewis, as to his courage, particularly his courage in advocating the letting of the contract for the great Ashokan Reservoir to a firm of contractors of established reputation at a price 20% in excess of the lowest bidder for that contract. Under his advice this contract was let to Winston and Company, composed of James O. Winston and Thomas Winston and my charming friend, Jules Breuchaud.

Among my other activities, an activity which I do not regret, and I am sorry to say that in my advancing years—and I am so old that it is generally believed that I am at least 250 years old—you may not know it, but it is an absolute fact that when they celebrated the 250th anniversary of my town in 1908, it was generally conceded that it was a celebration of my own 250th birthday; so that I have long lived there, and know the traditions of the mountains—and among my activities which I do not regret is the fact that I have to some extent been the advisor of these contractors from the time they took this contract under the approval of Mr. Smith down to this day.

While I have been at the bar 42 years—for 27 of which I was connected with the Department of Justice, Prosecuting Officer, County Clerk, Justice of the Supreme Court—during that entire time I have never known any more scrupulous men than these contractors, Winston and Company. They have done exactly as they agreed to do with the City of New York, and more than they agreed to do. They have had the approval, all the way through, of the Chief Engineer of this Board, Mr. Smith; and, as Mr. Lewis well said in his address to you, subsequent events absolutely justified the attitude and determination of Mr. Smith in awarding the contract to that firm; and it was through their co-operation and his superb planning of the whole scheme that the City of New York has this supply of abundant, pure, sparkling water to-day.

Now, except the engineers here, Mr. Smith, Mr. Honness, Mr. Breuchaud, and Mr. Strauss—you know nothing about the wonderful character of this water. I had occasion recently to examine the most distinguished geologists in this hemisphere—Grabau, of Columbia; Merrill, of Yale; Burrell, of Washington; Clark, of New York—particularly as to the age of the Catskill Mountains. I found that they were even older than the Board of Water Supply.

There are two schools of thought regarding the geological formation of the Catskill Mountains, one that they are the result of sedimentary deposits, the other maintains that they are the result of the erosion of the ice cap, as it came down from the mountains of the North. It was agreed by all that these mountains are 300 000 000 years old. It was also agreed that there was no impure or polluting element in this water from the old Devonian formation, entirely above any carbonaceous deposit; above iron, coal, copper, zinc, lead.

Therefore, this water, which you get from the Ashokan Reservoir, the site or location of which was selected by this Chief Engineer, comes over this old sandstone bed, and comes down to you pure, free from any possible pollution. You realize what a beneficial thing that is for New York; no typhoid fever, no germs, no bacteria, no protoplasmic substances to interfere with the advance of this great wave of prohibition which is sweeping over the country. It will supply you all with every needful drink.

What does it mean to you that you should have such a supply? You owe its selection to this man, who is to get this decoration to-night. The John Fritz Medal is not a sufficient decoration. He ought to be elected the great, high panjandrum of the prohibitionists of the world.

This colossal work required a wonderful intellectual scope. It required more than mere mathematical ability. It required prescience, vision, imagination. It required the faculty to see from the beginning the completion of the great scheme; and that is given to few men in this world. There are many of us who can take a single task and execute it; but it is given to few of us to combine in our imagination and vision a grand scheme such as is involved in the creation of this Catskill Mountain water supply. I suppose that those of you who have not been up there will go, and there you will see a natural reservoir formed by ranges of mountains, this stream coming down over this old red sandstone bed, gathered into this vast basin, with its one hundred and sixty-six billions of gallons of water; and in a few years you will see the Schoharie River, diverted from its channel, carried through the Catskill Mountains into this reservoir to supply you with additional hundreds of millions of gallons of water per day, which you will need in the dozen years required to complete that tunnel.

This man planned it all. He had the foresight, the vision, to see it all in the beginning. Now you may not know that there were other sources of supply suggested before this scheme was decided upon. There was talk of diverting the waters of the Hudson River in the vicinity of Kingston—a town that I sometimes visit when I venture out of my mountain fastness—and carrying that down here, and filtering it and supplying it to New York. The Hudson River has become little more than a sewer, and that plan was abandoned because the water was not suitable.

The Adirondack Mountains were talked of; a vast chain of lakes, but the distances were too great; the transparent waters of Lake George and Lake Champlain, but they were too far away; a river in Connecticut, but that was barred because it was taking the waters from another State; New Jersey was spoken of; and, at last, our friend here, with his associate engineers, decided upon the Ashokan Valley as the place where this dam and reservoir should be constructed.

Have you engineers seen the great reservoirs of the world? Many of you, I take it, have seen the great aqueducts of the Romans. Mr. Lewis has said that we build our aqueducts under the ground. The Romans built their aqueducts above the ground. There are remains of Roman aqueducts in Germany, in France, and other countries. They were all above ground, subject to the influences of the elements and of decay, and they exist only in isolated, broken patches, as it were.

An aqueduct above the ground was spoken of, a structure like the aqueduct above High Bridge—the old aqueduct carrying the water of the Croton River—which is built after the style of the ancient Roman aqueduct across the Campagna.

The siphon carries the water under the Hudson River, as described to you by Mr. Lewis, a great work due to our distinguished friend. It would be a labor of joy to paint the other side of the picture. I should be glad; it would be a great opportunity for me to relate here—I hope, to a sympathetic audience—my disagreements with this gentleman. I do not want you to think that I love him without limitation. I want you always to remember that I have in my mind, the great Aristides of Athens.

You will remember that Aristides was so praised for his good works and just conduct that the Athenians grew tired of hearing his praises. They pulled down his monument in the market place (as we pulled down the monument of Frederick the Great at Washington the other day) and exiled him because he had been praised so highly; and I do not want to go so far in the praise of this man that you will treat him as the Athenians treated Aristides.

You all have seen the Cathedral of St. Paul's in London, built by the great architect, Sir Christopher Wren. When it was proposed that they build, in place of the statue of Queen Anne in the Plaza in front of St. Paul's, a monument to Sir Christopher, it was suggested by the Mayor and the Commonalty of the City of London that they put an inscription on that cathedral which would surpass in dignity, and in a lesson to posterity, any monument which they might devise or erect; and they placed on the walls of St. Paul's an inscription which might well be placed on the Ashokan Dam to the memory of Mr. Smith: *Si Monumentum Requiris, Circumspice.*

The Chairman.—Now, after these two eloquent addresses, the presentation of the medal itself will take place. The medal will be presented by Mr. Ambrose Swasey, Past-President of the American Society of Mechanical Engineers, Founder of the Engineering Foundation, and agreed by all to be the Dean of the Engineering Profession in America. After the presentation of the medal there will be a response by the medalist, Mr. J. Waldo Smith.

AMBROSE SWASEY.—Mr. Chairman, Ladies and Gentlemen, and Friends: We are always glad of the opportunity of taking some part in honoring those who have won distinction as we journey along together through life, and these occasions for the presentation of the John Fritz Medal have been especially gratifying to us and inspiring, for the recipients of the medal have been men of noted achievements in science and in industry, men we have loved to honor, and men from whom we have greatly enjoyed receiving their expressions of appreciation.

I remember, when traveling in the Far East, receiving a letter from Sir William White, shortly after he had been informed by Mr. Hunt, who was then Secretary of the Board of Award, that the John Fritz Medal had been awarded to him.

In the letter Sir William said "I count it as one of the greatest honors that has ever been bestowed upon me by my professional brethren."

Surely, friends, in honoring this man we have honored ourselves. And, now, J. Waldo Smith, the John Fritz Medal Board of Award, because of your standing as a man, and your high character, because of your achievements as an engineer, have awarded you this medal, and having been the Chairman of the Board at the time the award was made, it is indeed a pleasant duty and a great privilege for me, on behalf of the Board, to present this medal to you, together with this diploma; and may I add, it is my hope, which I am sure is shared by all those who know you, and know of you, that for many years you may continue in the splendid work in which you have been engaged for the advancement of civilization and for the benefit of humanity.

J. WALDO SMITH.—Col. Carty, the Committee, Guests, and Assembled People: As I sat here and listened to the fluent and persuasive speakers, I wished that I might attain, for a minute or two, a state of mind where I could believe that all the complimentary things that they have said were deserved; but I fear they have viewed this undertaking through glasses tinted with the color of the morning, and from too favorable a standpoint.

However, it is idle for me to pretend that I am not deeply moved with the tribute of this meeting. I would be insincere were I to create the impression that I am not most grateful for the generous, gracious words of this talented scholar and distinguished jurist from Ulster County, and of the ranking engineer of the City of New York in commendation of the work accomplished. For the very beautiful and artistic medal, typifying the highest honor in the gift of engineers, I am profoundly grateful and appreciative. I shall never cease to be filled with wonder and surprise that I was chosen for this honor, a wonder which only grows with consideration of the previous recipients.

On the other hand, it gives me great pride, joy, and happiness to think that it is an honor in which very many others can rightfully claim a large share. Some are in this room; some are serving the Government in its present-day vital activities; and some are in a far country fighting the battles of their nation and of humanity. It would be the height of presumption to assume that this medal was not intended as a recognition of the construction of the Catskill Water Supply, and of the work of all those who have contributed to its success, and I do so consider it.

It was my privilege to know that grand old man in whose honor the medal was founded, to have been privileged even to call him Uncle John, to contribute to the fund, and to take part in that meeting on August 21st, 1902, at which the first medal was presented to John Fritz. That date marked the first formal co-operation of the four national societies, a movement of slow growth, with many disappointments, but always tending toward closer union.

The United Engineering Society has, so far as its occupancy of this building is concerned, held three of these engineering societies together. The establishment of the Engineering Foundation, through the great generosity of Mr. Swasey, was a long step in advance, perhaps the longest, that has been taken to date. The formation, during the last year, of the Engineering Council, of which so much was expected, adds another bond of fellowship; and now, that great and influential organization, the American Society of Civil Engineers, has given up its exclusiveness, and has joined in the occupancy of this building. So, with the four national societies housed under one roof and joining in the use of a common library, the opportunity is afforded of closer relations.

The time is opportune, and the need never was greater. How this may be brought about is one of the questions that deserves the most careful consideration. Possibly the solution of a closer union lies in an Institute of Engineers, or an American Society of Engineers with chapters for the various branches of engineering, and a strong, centralized government through which a proper co-ordination can be effected.

But, more than all this, engineers should have more consideration for each other. They should not be so prone to condemn, but ever seek to be helpful, one to another. In this great and monstrous war, engineers, as individuals, are doing a wonderful work. They are found in every branch of the military service, and in all the activities of the

Government. Their services are being sought and recognized, and they are working together toward a common end and aim.

It seems to me that this unity of purpose should serve as an example to those who have not had the privilege of rendering direct service, and it should indicate to all technical men and engineers that inspiration to better things comes only through unity of organization, and that only through unity of purpose, forcefully expressed by accredited representatives, can the influence which they hold, be made significant and become a substantial fact.

The organization of more engineering societies, national in scope, is all wrong, and can result in no advantage. Progress can only be made through the present societies becoming increasingly more useful to their members and securing closer co-operation among themselves.

These are troublous times, and the future looks none too bright, but we view it with courage and confidence. It seems as if the entire universe were at war, with all the nations arrayed against each other. And what is it all about, what are we fighting for—the phrase has been used so much for the last year—"to make the world safe for democracy?" If this means that we are trying to force democracy as a form of government on the other nations, then we are just as despotic as the nations we are fighting against. Oh no. We are not fighting for this. We are fighting to make the world safe for ourselves and our successors; to keep the war away from our homes, our lands, and our people. We are fighting for liberty, right, and honor. We are fighting to avenge the unspeakable crimes that have been committed under the guise of an alliance with God. We are fighting to crush that despotism which knows no law but necessity, is guided only by the lust of conquest, and, by its alliance with the unspeakable Turk, has laid bare its adherence to every principle of pillage, murder, rape, and mutilation. We are fighting to establish and maintain that universal principle of humanity, the inherent right of every one brought into this world to life, liberty, and the pursuit of happiness. The force and power of elemental justice cannot be overcome. It will live forever. Our cause—the simple cause of humanity—must prevail, and we must and will win.

What shall be said of this splendid lot of men who have gone abroad, and of those who are preparing to go? They are leaving their homes and their families, and they are going cheerfully and eagerly to take their places in the line. These societies should be very proud of the record of their membership. Nearly fifteen per cent. are engaged somewhere in war service, and the number ever increases. Presumably this percentage holds good for the entire Engineering Profession. But in the many letters that I have received from abroad and many others I have read, there is an almost universal sentiment of fear expressed. Such a sentiment seems very strange to us who know these courageous, splendid fellows who have gone away, and you may well ask of what are they afraid. Well, they are afraid that they may get in the thick of the combat. They fear that there may not be a full co-operation and co-ordination; that personal ambition and jealousy may create discord, so that the allied armies may not be able to put forth a concerted effort. They are afraid, too, that due to the machinations of the pacifists and the seeming inability of our people to agree on a programme to put every ounce of their effort toward its fulfillment, they will be handicapped by lack of material and equipment, and that their full effort cannot be exerted.

They fear more than anything else that there may be a negotiated and inconclusive peace before the inhuman invader is brought to a full realization of what wanton destruction, cruelty and outrage mean, by having his country invaded, and his cities and villages laid waste. The whole thought and ambition is that the power of despotism in the whole world must be broken and destroyed; and that the people, who individually work and give and make sacrifices shall be given the privilege of determining whether they shall or shall not be herded as slaves and driven to slaughter.

I presume every one who has had the privilege of being the principal executive officer in a large undertaking, and particularly when he has had the rare privilege of an absolutely fresh start and has brought together a new organization, has had or should have had certain hopes and ambitions. This was the case with us on the Catskill Aqueduct. It was our constant endeavor to encourage the highest degree of *esprit de corps,* as it was realized that this was the foundation on which the edifice of any successful effort must be constructed. We ever held in view the justice of giving to the engineer that proper recognition in compensation, position, and influence, which, measured by the results accomplished, was his just due. We sought always so far as possible to develop every man by thrusting responsibility on him, and at the same time not neglecting his guidance and instruction, we sought to keep out jealousy, and to secure from all the highest degree of co-operation and consideration, each for the other.

We tried to see that no part of this work was segregated or fenced about to the exclusion of men engaged on other parts of it, believing that to do so would result in lack of interest and appreciation of what it was sought to accomplish.

Believing that the contractor on a public work is just as much a partner of the undertaking as the engineer representing the governing authority, a firm effort was made throughout to establish a better working basis between the engineer and the contractors and their representatives. We thought that to work with them and not against them would secure a more perfect result, and, in the end, would avoid additional expense and litigation. In order that the elements of doubt and uncertainty usually attending contract work should, to a great extent, be eliminated, it was our aim to make the preliminary investigations as thorough and complete as possible, and to prepare plans and specifications which should contain all available and pertinent information and be as complete and definite as our best thought and effort could make them, so that the contractors could prepare their bids intelligently and size up accurately the business risk involved.

All this was done with a view that competition would be stimulated, that better and fairer bids would be obtained, and that more satisfactory ultimate results and greater economy would be secured. I do not know how far these hopes have been realized. I do know that the realization is far less than the anticipation, but I am contented in the consciousness that an earnest effort was put forth and some success attained.

I beg the indulgence of this audience for a few moments longer to say just a word or two to my personal associates of these many years, who are here. There may not be another opportunity so favorable; and in this term "associates" I include very many, who, though they had no direct connection with the work, have yet been very helpful.

A very distinguished diplomat and author has, in a very few and simple words, expressed what I feel. It is this:

> "When you attain that which you have desired, you shall think more of the kindness of your fortune than the greatness of your skill. This will make you grateful and willing to share with others what Providence has bestowed upon you. And truly this is both reasonable and profitable, for it is but little any of us would catch in the world were not our luck greater than our deserts."

I am not only willing, but I am glad, to share with others, and I would be most unhappy if I could not share any honor or credit which I have received, or may receive in the future with you. By chance, by the mere accidental turn of Fortune's wheel, which gave the opportunity, for opportunity is seldom if ever of our own making, it was my privilege to lead; but there was little, very little, I could do, except to encourage, to try to keep trouble away, so that you could all put forth your best efforts; at times perhaps to fight your battles. The most I could do was to say "yes" or "no" to propositions that you advanced, with the best information and advice which could be secured. It was inconceivable that the answer could always have been right, but any answer that is not fundamentally and intrinsically wrong is infinitely better than delay, and contributes far more to true efficiency and economy.

Individuals or groups of individuals in the organization have created or proposed all the new things, all the special features of the work. This naturally is the situation on most, if not all, large works; but possibly it is not always so freely admitted. Some bold things have been done, of which nothing now can be said in detail, but for which credit is sure to come later. That credit is yours, and I want every one to know it is yours.

The whole underlying, fundamental reason of all the success is this cordial co-operation and consideration which each has felt for the other; and the fact that the administrative and executive bureaus have worked together and in perfect harmony and have believed in each other.

It is now 12 years and more since this association began, a quarter, or nearly a quarter, of one's useful life, and it is hoped that you have acquired something in these years that is going to help you in the future. It is hoped that every one will look back on these years always with pleasure, and that you have acquired through experience and association something which will help you upward as you go onward.

You will never know how much of thanks and gratitude I hold for the high degree of loyalty you always gave, and for the ability, vision, and talent you brought to the work.

Adjourned.

ANNOUNCEMENTS

The Reading Room of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

June 5th, 1918.—8.30 P. M.—A regular business meeting will be held, and a paper by L. R. Jorgensen, M. Am. Soc. C. E., entitled "Improving Arch Action in Arch Dams", will be presented for discussion.

This paper is printed in this number of *Proceedings.*

ANNUAL CONVENTION ABANDONED

The Board of Direction has decided that the Annual Convention of 1918 shall be abandoned, on account of War Conditions. Among the reasons for this action are: the absence of many members of the Society in the service of the country; the inappropriateness of social functions at this time; the limitation of transportation facilities; and the advisability of the practice of economy along all lines.

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction to the members who have made use of the resources of the Society in this manner has been expressed frequently, and leaves little doubt that if it were generally known to engineers that such assistance could be had, many would avail themselves of it.

On October 1st, 1916, the Library of the American Society of Civil Engineers ceased to exist as such, and was merged in the Engineering Societies Library, adding 67 000 volumes to the collection, which comprises also the former libraries of the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, and now has a total of 133 000 volumes and pamphlets. Containing, as the Library now does, the special collections mentioned, its scope is broadened, and, as it receives an unusually large number of technical periodicals, it is well equipped to continue the service formerly rendered by the Society Library.

The Engineering Societies Library offers this service at a cost which is trifling compared with the value of the time of an engineer who personally looks up such matters, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

It sometimes happens that references are found which are not readily accessible to the person for whom the search is made. In that case the Library is prepared to furnish photographic copies of the material at a small price per page. This method is particularly useful when there are drawings or figures in the text, which would be very expensive to reproduce by hand.

The Library is also able to provide translations of articles in foreign languages when desired.

Requests for searches, copies, translations, etc., should be addressed to the Director, Engineering Societies Library, 29 West 39th Street, New York City, who will gladly give information concerning the charges for the various kinds of service.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings.*

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion will be published as heretofore in *Proceedings,* and set down for presentation to a future meeting of the Society, and, on these, oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which from their mathematical or technical nature, in the opinion of the Committee, are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions only will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions.*

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 35 of the Year Book for 1918.

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association, Organized 1905.

Jerome Newman, President; Nathan A. Bowers, Secretary-Treasurer, 502 Rialto Building, San Francisco, Cal.

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Palace Hotel, on the third Tuesday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at noon, every Wednesday, at the Engineers' Club, 57 Post Street, where special tables are reserved for members and guests of the Association.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

Colorado Association, Organized 1908.

Robert Follansbee, President; L. R. Hinman, Secretary-Treasurer, 1400 West Colfax Avenue, Denver, Colo.

The meetings of the Colorado Association of Members of the American Society of Civil Engineers (Denver, Colo.) are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesday at 12.30 P. M., at Daniels and Fisher's.

Visiting members are urged to attend the meetings and luncheons.

Atlanta Association, Organized 1912.

B. M. Hall, President; W. C. Spiker, Secretary-Treasurer, 1408 Candler Building, Atlanta, Ga.

Baltimore Association, Organized 1914.

Mason D. Pratt, President; Charles J. Tilden, Secretary-Treasurer, The Johns Hopkins University, Baltimore, Md.

Cleveland Association, Organized 1914.

Harry Fuller, President; George H. Tinker, Secretary-Treasurer, 516 Columbia Building, Cleveland, Ohio.

Detroit Association, Organized 1916.

T. A. Leisen, President; Clarence W. Hubbell, Secretary, 2348 Penobscot Building, Detroit, Mich.

The regular meetings of the Association are held on the second Friday of December, April, and October, the last being the Annual Meeting.

District of Columbia Association, Organized 1916.

A. P. Davis, President; John C. Hoyt, Secretary-Treasurer, U. S. Geological Survey, Washington, D. C.

Duluth Association, Organized 1917.

F. E. House, President; Walter G. Zimmermann, Secretary, Wolvin Building, Duluth, Minn.

The regular meetings of the Association are held at noon on the third Monday of each month (usually at the Kitchi Gamma Club), with luncheon, followed by a short business session and the reading of papers. Visiting members of the American Society of Civil Engineers can secure from the Secretary definite information relating to the meetings, at which they will be welcomed. The Annual Meeting is held on the third Monday in May.

(Abstract of Minutes of Meeting)

April 15th, 1918.—The meeting was called to order; President F. E. House in the chair; Walter G. Zimmermann, Secretary; and present, also, 18 members.

The Committee on Organization of a Duluth Engineers' Society, W. H. Hoyt, Chairman, reported that a preliminary meeting for discussion relative to the organization of the proposed society would be held on Monday evening, May 20th, 1918, at a dinner at the Kitchi Gamma Club, to which all members of the four National Societies are to be invited.

On motion, duly seconded, the Committee on Publication of Papers was instructed to have copies of all papers to be presented before the Association ready for distribution at the meetings at which such papers are to be read, in order to facilitate discussion.

A paper by Lyonel Ayres, City Engineer of Duluth, entitled "Paved Highways" was presented by the author.

Adjourned.

Illinois Association, Organized 1916.

A. S. Baldwin, President; Edgar S. Nethercut, Secretary-Treasurer, 705 Michigan Ave., Evanston, Ill.

The regular meetings of the Association are held on the second Monday of March, June, September, and December, the last being the Annual Meeting. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary.

Louisiana Association, Organized 1914.

W. B. Gregory, President; Charles W. Okey, Secretary, Tulane University, New Orleans, La.

The regular meetings of the Association are held at The Cabildo, New Orleans, La., on the first Monday of January, April, July, and October.

Nebraska Association, Organized 1917.

George L. Campen, President; Homer V. Knouse, Secretary-Treasurer, 115 City Hall, Omaha, Nebr.

Regular meetings of the Association are held on the first Saturday of each month, except July and August, and at such places as may be appointed from time to time by the Executive Committee. The Annual Meeting is held in Lincoln, Nebr., on the second Friday in January.

An "Engineers' Round Table" is reserved daily for luncheons, at Courtenay's Restaurant, 17th and Douglas Streets, Omaha, to which all engineers are invited. Visiting members of the Society are especially urged to communicate with the Secretary when in the city.

Northwestern Association, Organized 1914.

P. E. Thian, President; Ralph D. Thomas, Secretary, 508 South First Street, Minneapolis, Minn.

The meetings of the Association are held bi-monthly, alternating between St. Paul and Minneapolis, on the third Friday of each month. Information as to the time and place of such meetings will be furnished on application to the Secretary.

Philadelphia Association, Organized 1913.

Henry H. Quimby, President; C. W. Thorn, Secretary, 1313 South Broad Street, Philadelphia, Pa.

The regular meetings of the Association are held at the Engineers' Club of Philadelphia, 1317 Spruce Street, on the first Monday in January, April, and October, the last being the Annual Meeting.

Pittsburgh Association, Organized 1917.

Richard Khuen, Jr., President; A. B. McGrew, Secretary-Treasurer, 2111 Farmers Bank Building, Pittsburgh, Pa.

The Annual Meeting of the Association is held on the first Monday in October. The time and place of other meetings are not fixed, but this information will be furnished on application to the Secretary.

Portland, Ore., Association, Organized 1913.

Philip H. Dater, President; C. P. Keyser, Secretary, 1147 East Yamhill Street, Portland, Ore.

St. Louis Association, Organized 1888 (Constitution Approved by Board, 1914).

J. A. Ockerson, President; C. M. Daily, Secretary-Treasurer, 34 East Grand Avenue, St. Louis, Mo.

The Annual Meeting of the Association for the election of officers and for the transaction of business, is held on the fourth Monday in November. Two meetings each year, for the presentation and discussion of technical papers, are held in the Auditorium of the Engineers Club of St. Louis and are open to members of the Associated Societies. Other "get-together" meetings are held regularly for dinner or luncheon on the fourth Monday of each month except July, August, and November.

(Abstract of Minutes of Meeting)

April 29th, 1918.—The meeting was called to order at the American Hotel, at 6.30 P. M.; President Ockerson in the chair; C. M. Daily, Secretary; and present, also, 21 members and guests.

The minutes of the preceding meeting were read and approved.

A communication from the American Association of Engineers asking for data on the Society's activities in war, employment for members, education for engineering students, and its publicity programme, was read by President Ockerson, who was requested to reply to the communication.

Professor W. E. McCourt addressed the meeting on "War Materials and War Minerals."

The work and organization of the National Engineering Council and the variety of work which comes before it, were described by Mr. Philip N. Moore.

Mr. Edward E. Wall reported on the meeting of the Board of Direction of April 16th, 1918.

Adjourned.

San Diego Association, Organized 1915.

N. B. Kellogg, President; J. R. Comly, Secretary-Treasurer, 4105 Falcon Street, San Diego, Cal.

Seattle Association, Organized 1913.

A. S. Downey, President; Phil. A. Franklin, Secretary, Care, City Engineer's Office, County-City Building, Seattle, Wash.

The regular monthly meetings and luncheons of the Association are held at the Frye Hotel, 3d Avenue and Yesler Way, at 12.15 P. M., on the last Monday of each month. All members, in any grade, of the American Society of Civil Engineers are cordially invited to attend the meetings when in the vicinity.

Southern California Association, Organized 1914.

Louis C. Hill, President; H. W. Dennis, Secretary, Edison Building, Los Angeles, Cal.

The Southern California Association of Members of the American Society of Civil Engineers (Los Angeles, Cal.) holds regular bi-monthly meetings with banquet, at Hotel Clark, on the second Wednesday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M., every Thursday and the place of meeting may be ascertained from the Secretary.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in Los Angeles, and any such member will be gladly welcomed as a guest at any of the meetings or luncheons.

Spokane Association, Organized 1914.

J. C. Ralston, President; B. J. Garnett, Secretary, City Hall, Spokane, Wash.

The regular meetings of the Association are held on the second Friday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary.

Visiting members are invited to attend the meetings and luncheons.

Texas Association, Organized 1913.

R. C. Gowdy, President; J. H. Brillhart, Secretary, Care, Mosher Mfg. Co., Dallas, Tex.

(Abstract of Minutes of Meeting)

March 9th, 1918.—The meeting was called to order at the University Club, Dallas, Tex., at 10.30 A. M.; First Vice-President R. C. Gowdy in the chair; J. H. Brillhart, Secretary; and present, also, 17 members.

The reading of the minutes of the previous meeting was waived.

The following candidates were elected to membership: Messrs. J. L. O'Hearn, C. E. Washburn, H. E. Burns, E. L. Myers, Charles Saville, and F. L. Chase.

On motion, duly seconded, the report* of the Committee on the Relations of Local Associations to the Parent Society, etc., was ordered read and discussed. The following report with amendments was adopted:

"The Relations of Local Associations.

"*Initiation.*—It is the sense of this meeting that the Rule be approved. Carried.

"*Constitution and By-Laws.*—It is the sense of this meeting that this Rule be approved; especially recognizing the authority granted to Local Associations to exercise their influence in properly solving Public Engineering Problems, not of a national character. Carried.

"*Reports.*—Approved. Carried.

"*New Members.*—It would seem best to word this Rule so that Local Associations *may* investigate and officially report on candidates for admission, and *must* do so if the Secretary of the Society so requests. Carried.

"*Restriction in Activity.*—Approved. Carried.

"*Ethics.*—Moved, seconded, and carried that recommendation of National Association (regarding Ethics) be approved. The Board of Directors of this Local Section are hereby granted authority to act as the committee of investigation appointing sub-committee if necessary. Carried.

"*Grievances.*—Approved. Carried.

"*Co-Operation.*—Approved. Carried.

"*Local Societies.*—Approved. Carried.

"*Engineers.*—Approved. Carried.

"*Relations of Local Societies to the Public.*—Approved. Carried.

"*Local Affairs.*—Carried.

"*State Affairs.*—Carried.

"*Rebate.*—It is the sense of this meeting that the Parent Society be and hereby is, requested to remit to the Treasury of this Association annually, an amount equal at least to 20% of the annual dues paid to the Parent Society by individual members of this Section. Carried."

On motion, duly seconded, the verbal report of the Treasurer was accepted, and he was ordered to make a full written report in the minutes of this meeting.

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* This report was published in May, 1917, *Proceedings*, p. 327.

On motion, duly seconded, the Secretary was ordered to compile an Honor Roll of members of the Association in the Service, including those on the Reserve List.

On motion, duly seconded, it was decided to select a city to be the permanent headquarters of the Association, where the Secretary may have an office, and that the Board of Directors be instructed to designate such city as the place for holding the Annual Meetings of the Association, it being understood that if, in the opinion of the Board, it is imperative to designate another city, authority to make such change is hereby authorized.

On motion, duly seconded, it was decided that, until due notice to the contrary is given by the Board of Directors, the Association shall continue to hold regularly its annual and semi-annual meetings.

On motion, duly seconded, the Secretary was ordered to mail a notice to all members of the Association, except those in active military service, relative to the payment of the annual dues, and to make a full report on the subject at the next general meeting.

The following officers were elected: R. C. Gowdy, President; R. J. Potts, First Vice-President; Hans Helland, Second Vice-President; and J. H. Brillhart, Secretary-Treasurer, with the understanding that Dallas is to be the headquarters of the Association. Messrs. C. H. Chamberlin and J. M. Howe automatically became members of the Board of Directors.

On motion, duly seconded, the dues of all members in active military service were remitted during their period of service.

After a Progress Report by Mr. J. C. Nagle on the activities of the Legislative Committee had been presented, it was moved and carried that the Committee be continued, and that two more members, to be named by the President, be added to it.

On motion, duly seconded, the Secretary was instructed to write a letter of thanks to the officers of the University Club for the use of its rooms.

A paper by Mr. R. G. Tyler, entitled "Purification of Sewage by Aeration in the Presence of Activated Sludge", was presented by the author, and the subject was discussed by Messrs. Nagle, Saville, Myers, Bartlett, and Love.

Maj. W. P. Rothrock, of the Quartermaster's Department, U. S. A., addressed the meeting on the construction of Camp Logan, at Houston, Tex.

A paper by Mr. C. T. Bartlett, entitled "Some Considerations Concerning Stream Run-off in Relation to Rainfall", was presented by the author, followed by discussion by Messrs. Nagle, Love, Chamblin, and Tyler.

On motion, duly seconded, a vote of thanks was extended to the Local Committee for courtesies extended.

Adjourned.

Utah Association, Organized 1916.

George L. Swendsen, President; H. S. Kleinschmidt, Secretary-Treasurer, 306 Dooly Building, Salt Lake City, Utah.

The Annual Meeting of the Association is held on the first Wednesday in April. The time of other meetings is not fixed, but this information will be furnished on application to the Secretary.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms, and at all meetings:

American Institute of Electrical Engineers, 25 West Thirty-ninth Street, New York City.

American Institute of Mining Engineers, 25 West Thirty-ninth Street, New York City.

American Society of Mechanical Engineers, 25 West Thirty-ninth Street, New York City.

Assoçiacão dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 176 Mansfield Street, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, Public Library, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Detroit Engineering Society, Detroit Board of Commerce Building, Detroit, Mich.

Engineering Association of Nashville, Commercial Club Building, Nashville, Tenn.

Engineering Association of New South Wales, 5 Elizabeth Street, Sydney, New South Wales, Australia.

Engineering Societies Club of Hawaii, E. F. Cykler, Secretary, Honolulu, Hawaii.

Engineers and Architects Club of Louisville, 1412 Starks Building, Louisville, Ky.

Engineers' Club of Baltimore, 6 West Eager Street, Baltimore, Md.

Engineers' Club of Kansas City, Robert S. Beard, Secretary, Third Floor, City Hall, Kansas City, Mo.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Club of Trenton, Trent Theatre Building, 12 North Warren Street, Trenton, N. J.

Engineers' Society of Northeastern Pennsylvania, 415 Washington Avenue, Scranton, Pa.

Engineers' Society of Pennsylvania, 31 South Front Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 568 Union Arcade Building, Pittsburgh, Pa.

Florida Engineering Society, J. R. Benton, Secretary, Gainesville, Fla.

Institute of Marine Engineers, The Minories, Tower Hill, London, E., England.

Institution of Civil Engineers, Great George Street, Westminster, S. W., London, England.

Institution of Engineers of the River Plate, Calle 25 de Mayo 195, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, State Museum Building, Chartres and St. Ann Streets, New Orleans, La.

Memphis Engineers' Club, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Montana Society of Engineers, Butte, Mont.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Oregon Society of Civil Engineers, Portland, Ore.

Pacific Northwest Society of Engineers, 803 Central Building, Seattle, Wash.

Rochester Engineering Society, Rochester, N. Y.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Societe des Ingenieurs Civils de France, 19 rue Blanche, Paris, France.

Society of Engineers, 17 Victoria Street, Westminster, S. W., London, England.

Southwestern Society of Engineers, C. E. Barglebaugh, Secretary, 703 First National Bank Building, El Paso, Tex.

Svenska Teknologforeningen, Brunkebergstorg 18, Stockholm, Sweden.

Tekniske Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Vermont Society of Engineers, George A. Reed, Secretary, Montpelier, Vt.

Western Society of Engineers, 1735 Monadnock Block, Chicago, Ill.

ACCESSIONS TO THE ENGINEERING SOCIETIES LIBRARY

(From April 1st to May 1st, 1918)

DONATIONS*

The statements made in these notices are taken from the books themselves, and this Society is not responsible for them.

ELECTRICAL MEASUREMENTS:

A Practical Handbook Covering the Design and Construction of Measuring Instruments and Their Uses in Measurement of Current, Resistance, and Commercial Power, with Special Reference to Watt-Hour and Maximum Demand Meters. By O. J. Bushnell and A. G. Turnbull. Chic., American Technical Society, 1914. 171 pp., 139 illus., 2 pl., 8 x 6 in., cloth. $1.00.

The aim of the authors has been to supply an adequate description of the instruments and methods used for the measurement of electrical energy, and to show by diagrams exactly how meters should be connected under all conditions.

RADIO-TELEPHONY.

By Alfred N. Goldsmith. N. Y., The Wireless Press, Inc. (copyright 1918). 247 pp., 226 illus., 9 x 6 in., cloth. $1.25.

The author has attempted in this work to give a full description of present methods of radio-telephony and of the various types of apparatus used. The first systematic exposition of the subject to appear since 1907.

POWER STATIONS AND TRANSMISSION:

A Comprehensive Treatise on Electric Power Station Equipment, Design, and Management, and the Erection and Maintenance of Proper Transmission Lines. By George C. Shaad. Chic., American Technical Society, 1917. 180 pp., 50 illus., 3 pl., 10 tab., 8 x 6 in., cloth. $1.00.

Presents concisely the important features of the topic. The treatment is largely descriptive and non-mathematical.

TEXT-BOOK OF ADVANCED MACHINE WORK:

Prepared for Students in Technical, Manual Training, and Trade Schools, and for the Apprentice and the Machinist in the Shop. By Robert H. Smith. 4th ed., rev. and enl. Bost., Industrial Education Book Co. (copyright 1916). 648 pp., 680 illus., 44 tab., 8 x 5 in., cloth. $3.00.

A continuation of the author's "Principles of Machine Work". This volume treats of engine lathe work, drilling and boring machines, grinding, planing, milling, gear cutting, and tool making. Careful explanations are given for each variety of work.

MACHINE SHOP PRACTICE.

By William B. Hartman. N. Y. and Lond., D. Appleton & Co., 1917. 247 pp., 141 illus., 4 pl., 10 tab., 7 x 5 in., cloth. $1.10.

A presentation of the elementary principles of machine shop practice, intended for the instruction of beginners. Mathematical calculations are confined to the use of simple arithmetic.

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*Unless otherwise specified, books in this list have been donated by the publishers.

INTERNAL COMBUSTION ENGINE MANUAL.

By F. W. Sterling. 4th ed. Wash., R. Beresford, 1917. 168 pp., 10 x 6 in., cloth. $2.00.

This manual, representing the course on internal combustion engines given at the United States Naval Academy, has been rewritten, enlarged, and brought up to date. It now covers the theory and practice of these engines without including mathematical demonstrations and formulas. Particular attention is given to the engines used by the Navy and to aviation engines.

GALVANIZING AND TINNING:

A Practical Treatise on the Coating of Metal with Zinc and Tin by the Hot Dipping, Electro-Galvanizing, Sherardizing, and Metal Spraying Processes, with Information on Design, Installation, and Equipment of Plants. By W. T. Flanders. N. Y., David Williams Co., 1916. 350 pp., 142 illus., 3 charts, 5 tab., 9 x 6 in., cloth. $4.00. (Donated by the U. P. C. Book Co.)

Discusses the various processes in a practical way, describing the machinery, materials, and operations in detail. Intended as a guide in the installation and operation of galvanizing and tinning plants.

MECHANICS OF THE HOUSEHOLD:

A Course of Study Devoted to Domestic Machinery and Household Mechanical Appliances. By E. S. Keene. N. Y., McGraw-Hill Book Company, Inc.; Lond., Hill Publishing Company, Ltd., 1918. 10 + 391 pp., 273 illus., 11 tab., 8 x 6 in., cloth. $2.50.

This book is intended to be a presentation of the physical principles and mechanism used in the equipment that has been developed for domestic convenience. Equipment for heating, ventilating, water supply, sewage disposal, lighting, etc., is described.

AIRCRAFT MECHANICS' HANDBOOK:

A Collection of Facts and Suggestions from Factory and Flying Field to Assist in Caring for Modern Aircraft. By Fred H. Colvin. N. Y., McGraw-Hill Book Company, Inc.; Lond., Hill Publishing Company, Ltd., 1918. 402 pp., 193 illus., 28 tab., 7 x 5 in., flexible cloth. $3.00.

A manual of the best practice in inspecting, adjusting, and repairing airplanes, prepared for use by the machinists and riggers who are now being trained. Describes the construction, erection, and testing of the planes, the various engines in use, and the methods of caring for them. An account of the Canadian Training Camp at Borden is also given. Useful tables and a glossary are included.

AVIATION CHART:

Location of Airplane Power Plant Troubles Made Easy. By Victor W. Pagé. N. Y., The Norman W. Henley Publishing Co. [1918]. 46 x 32 in., paper. 50 cents.

A large chart outlining all parts of a typical airplane power plant, showing the points where trouble is apt to occur and suggesting remedies for the common defects. Intended especially for aviators and aviation mechanics on school and field duty.

MANUAL OF MILITARY AVIATION:

Prepared for the Use of Personnel of Aircraft Troops of the Army, National Guard, and Reserve Corps; Officers of the Army, National Guard, and Reserve Corps; Members of Military Training Camps; and Airmen in General. By Hollis Leroy Müller. Menasha, Wis., George Banta Publishing Co. (copyright 1917). 308 pp., 38 illus., 8 x 5 in., cloth. $2.50.

Contains the theoretical information necessary for efficient military aviation service. Intended for use as a text-book and as a reference work.

METALLURGICAL CALCULATIONS.

By Joseph W. Richards. N. Y., McGraw-Hill Book Company, Inc.; Lond., Hill Publishing Company, Ltd., 1918. 23 + 675 pp., tab., 10 x 7 in., cloth. $5.00.

A convenient one-volume edition of the work, in which errors occurring in earlier editions have been corrected, and to which new physical and chemical data have been added.

THE PRINCIPLES, OPERATION, AND PRODUCTS OF THE BLAST FURNACE.

By J. E. Johnson, Jr. N. Y., McGraw-Hill Book Company, Inc.; Lond., Hill Publishing Company, Ltd., 1918. 15 + 551 pp., 173 illus., 23 tab., 9 x 6 in., cloth. $5.00.

A thorough, detailed discussion of the operation of the blast furnace, including both the theoretical principles and the practice of the present day. Completes the author's treatise on the manufacture of pig-iron, begun in his work entitled "Blast Furnace Construction".

FORGING:

Manual of Practical Instruction in Hand Forging of Wrought Iron, Machine Steel, and Tool Steel; Drop Forging; and Heat Treatment of Steel, Including Annealing, Hardening, and Tempering. By John Jernberg. Chic., American Technical Society, 1917. 131 pp., 206 illus., 2 pl., 3 tab., 8 x 6 in., cloth. $1.00.

A concise account, intended primarily for students. Describes the methods and tools used in hand forging, as well as the usual shop practice in hardening, annealing, and tempering steel.

COLD DRAWN STEEL:

Bar Weights of Rounds, Flats, Hexagons, and Squares; Weight Tables for Plates; Metric Conversion Tables; Cold Drawn and Hot Rolled Extras, and Other Miscellaneous Tables (Cover title: Book of Weights). Issued by the Peerless Drawn Steel Co. Massillon, Ohio, The Peerless Drawn Steel Co., 1918. 145 pp., 52 tab., 8 x 5 in., flexible leather. $3.00.

Instead of giving only the weight per foot of steel bars of various sizes, this book gives the totals for bars of all the usual lengths in feet. A number of other useful tables are added.

FIELD ARTILLERYMAN'S GUIDE:

3-Inch Gun, 4.7- and 6-Inch Howitzer. Prepared by the Officers of the 108th (2d Pa.) Field Artillery. 2d rev. ed. Phila., P. Blakiston's Son & Co. (copyright 1918). 381 pp., 102 illus., 3 pl., 31 tab., 7 x 4 in., cloth. $1.75.

A pocket guide intended to serve the immediate needs of field artillerymen in the United States Army, by presenting the fundamentals of their duties.

SCIENTIFIC INDUSTRIAL EFFICIENCY:

By Dwight T. Farnham. Chic., Brick and Clay Record, 1917. 101 pp., 34 illus., 10 x 6 in., cloth. $2.00.

In this book the author has endeavored to describe some applications of scientific management which have come under his observation during his experience as an engineer and executive. The examples given are chiefly taken from the clay products industry.

THE SCIENCE OF MANAGEMENT:

By Frederic A. Parkhurst. Cleveland, The Author (copyright 1918). 203 pp., 7 tab., 9 x 6 in., cloth. $3.00.

A text-book prepared to accompany the author's course of thirty lectures, delivered during 1917-18 at the Case School of Applied Science.

CREATING CAPITAL:

Money-Making as an Aim in Business. By Frederick L. Lipman. Bost. and N. Y., Houghton Mifflin Co., 1918. 71 pp., 7 x 5 in., cloth. 75 cents.

HIGHER EDUCATION AND BUSINESS STANDARDS:

By Willard Eugene Hotchkiss. Bost. and N. Y., Houghton Mifflin Co., 1918. 109 pp., 7 x 5 in., cloth. $1.00. (Gift of the University of California Press.)

Two essays delivered at the University of California on the Weinstock Foundation, established for the discussion of various phases of the moral law in its bearing on business life under the new economic order.

WAR-TIME CONTROL OF INDUSTRY:

The Experience of England. By Howard L. Gray. N. Y., The Macmillan Company, 1918. 15 + 307 pp., 8 x 5 in., cloth. $1.75.

A summary of the development and status of governmental control of industry in Great Britain, arranged to show its successive stages. Part of the information was collected for the Commercial Economy Division of the Council of National Defense. The book concludes with a comparison of English and American experience.

COMPLETE LIST OF BASE PRICES, DIFFERENTIALS AND EXTRAS ON IRON,

Steel, and Non-Ferrous Products: Fixed under Government Supervision. Cleveland, Penton Publishing Co. (copyright 1918). 42 pp., 8 x 6 in., paper. $2.00.

A convenient summary of the Government prices. Prepared by the *Iron Trade Review* and presented to subscribers to that journal.

COAL GAS RESIDUALS.

By Frederick H. Wagner. 2d ed., rev. and enl. N. Y., McGraw-Hill Book Company, Inc.; Lond., Hill Publishing Company, Ltd., 1918. 13 + 244 pp., 45 illus., 12 pl. (10 folded), 7 diagrams, 32 tab., 9 x 6 in., cloth. $2.50.

The chief additions to this edition discuss the process of tar distillation and tar products, and give further information on the product derived from spent oxide, the production of nitric acid, naphthalene, benzol, and toluol. A chapter on the manufacture of sulfuric acid from spent oxide has also been added, and the typographical errors in the first edition have been corrected.

ARTIFICIAL DYE-STUFFS:

Their Nature, Manufacture, and Uses. By Albert R. J. Ramsey and H. Claude Weston. Lond., George Routledge & Sons, Ltd.; N. Y., E. P. Dutton & Co., 1917. 212 pp., 24 illus., 9 x 6 in., cloth. $1.60. (Donated by E. P. Dutton & Co.)

A brief introductory work on the artificial dye-stuff industry, written for students and business men with little knowledge of organic chemistry, in which the industrial processes of the manufacture of dye-stuffs, and the nature of the substances used, are explained at some length.

ELECTRO-DYNAMIC WAVE-THEORY OF PHYSICAL FORCES:

Announcing the Discovery of the Physical Cause of Magnetism, of Electro-dynamic Action, and of Universal Gravitation. Vol. 1, Bulletins 1 to 6, inclusive. By T. J. J. See. Lynn, Mass., Thomas P. Nichols & Son Co.; Lond., William Wesley & Son; Paris, A. Hermann et Fils, 1917. 14 + 158 pp., 21 diagrams, 4 pl., 1 chart, 6 tab. (1 folded), 12 x 10 in., paper. $5.00.

In these bulletins Dr. See presents his hypothesis that magnetism, electro-dynamic action, and universal gravitation are due to waves propagated with the velocity of light through the free ether and at slower rates through solid masses. The author believes that his investigations have finally solved the problem of the nature and mode of propagation of physical forces.

WAR ADMINISTRATION OF THE RAILWAYS

In the United States and Great Britain. By Frank Haigh Dixon and Julius H. Parmelee. (Carnegie Endowment for International Peace, Division of Economics and History. Preliminary Economic Studies of the War.) N. Y., Oxford University Press, 1918. 13 + 155 pp., 10 x 7 in., paper. $1.00. (Donated by the Carnegie Endowment for International Peace.)

An account of the methods used in the two countries and of the results achieved prior to December, 1917, during the period when the American railways were voluntarily co-operating with each other. The authors present a simple narrative, without attempting to draw conclusions.

STATE SANITATION:

A Review of the Work of the Massachusetts State Board of Health; Vol. 2. By George Chandler Whipple. Cambridge, Harvard University Press; Lond., Humphrey Milford, 1918. 452 pp., 17 illus., 3 pl., 1 por., 60 tab., 10 x 7 in., cloth. $2.50.

This volume contains abstracts of the leading articles on subjects relating to preventive medicine, hygiene, and sanitation which are scattered through the annual and special reports of the Massachusetts State Board of Health published between 1869 and 1914. In addition, thirty-four of the most important contributions to sanitation are reprinted, with some abridgement.

THE PRINCIPLES OF SANITARY TACTICS:

A Handbook on the Use of Medical Department Detachments and Organizations in Campaign. By Edward Lyman Munson. Menasha, Wis., George Banta Publishing Co. (copyright 1917). 305 pp., 13 maps (2 folded maps in covers), 8 x 5 in., cloth. $2.15.

The author's desire has been to provide a text-book which will standardize the methods of instructing line and medical officers in the tactical use of sanitary service with troops in campaign and will also give a thorough grounding in the fundamentals of sanitary tactics as a whole.

THE MODERN MILK PROBLEM:

In Sanitation, Economics, and Agriculture. By J. Scott MacNutt. N. Y., The Macmillan Company, 1917. 11 + 258 pp., 22 illus., 16 pl., 9 x 6 in., cloth. $2.00.

Written to supply a convenient survey of the main aspects of the milk problem, which will emphasize the practical and economic as well as the sanitary factors involved. Intended for health officials, dairymen, legislators, and others interested in better milk supplies.

AGRICULTURAL BACTERIOLOGY:

A Study of the Relation of Germ Life to the Farm with Laboratory Experiments for Students. Micro-organisms of Soil, Fertilizers, Sewage, Water, Dairy Products, Miscellaneous Farm Products, and of Diseases of Animals and Plants. By H. W. Conn. 3d ed., rev. by Harold Joel Conn. Phila., P. Blakiston's Son & Co. (copyright 1918). 10 + 357 pp., 63 illus., 8 x 6 in., cloth. $2.00.

The third edition has been brought up to date by the inclusion of the advances in bacteriological knowledge since the previous edition.

HANDBOOK OF HYDRAULICS:

For the Solution of Hydraulic Problems. By Horace Williams King. N. Y., McGraw-Hill Book Company, Inc.; Lond., Hill Publishing Company, Ltd., 1918. 16 + 424 pp., 91 illus., 112 tab., 2 diagrams, 7 x 4 in., flexible cloth. $3.00.

The author has attempted to simplify the work of the hydraulic engineer by studying critically the empirical formulas which have been devised and selecting those which are of value. These are presented with a description of their limitations and are accompanied by the necessary tables of coefficients. The twofold purpose of securing an accuracy consistent with the best experiments and of simplifying calculations has been kept in mind throughout the book.

ROLL OF HONOR

A List of Members of the Society Who are Serving in the Army or Navy of the United States or Any of Its Allies.*

Abbot, Frederic V. Brig.-Gen., Corps of Engrs., N. A., Office, Chief of Engrs., U. S. A., Washington, D. C.

Abbot, Frederick William. Lt.-Col., British Army; Metropolitan Club, New York City.

Acher, A. H. Maj., Corps of Engrs., U. S. A., 4th Engrs., Camp Greene, N. C.

Ackerman, Alexander S. 1st Lieut., Engrs., U. S. R.; 11 Francis St., Newport, R. I.

Ackerman, Arthur P. 1st Lieut., U. S. R., 33d Engrs.; Great Barrington, Mass.

Adams, Arthur. Maj., Ord., U. S. R.; Inspection Mgr., Albemarle Bldg., New York City.

Adams, Edward M. Maj., U. S. A., Care, The Adjt.-Gen., U. S. A., Washington, D. C.

Adams, Milton Jewell. Capt., U. S. R., Co. C, 114th Engrs., Camp Beauregard, Alexandria, La.

Adams, Raymond E. Capt., Q. M. C., U. S. R.; Asst. to the Q. M., S. E. D., Peoples Bldg., Charleston, S. C.

†**Agnew, Augustus Waterous.** Capt., 3d Canadian Pioneers.

Albert, Frederick W. Maj., U. S. R., 33d Engrs.; 23 Isham St., Burlington, Vt.

Alden, Herbert C. 1st Lieut., C. A. C., N. G. U. S., Fort Schuyler, N. Y.

Alden, Langford Taylor. Eléve Aspirant, 32^{me} Artillerie (French Army); Care Morgan, Harjes Cie., Boulevard Hausseman, Paris, France.

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* This list is made up from replies to a circular forwarded to members of the Society, and others, and is probably neither accurate nor complete. It is requested that the attention of the Secretary be called to any omissions or inaccuracies in order that they may be corrected in subsequent lists.

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Woolworth, W. H. Capt., U. S. A., Headquarters, 2d Brigade, 1st Div., Am. Exp. Force, France.

Wooten, William P. Maj., Corps of Engrs., U. S. A., Brownsville, Tex.

Wright, John Bertram. Capt., U. S. R., 9th Co. Engrs., Camp Lee, Petersburg, Va.

Wrightson, William D. Maj.; Chf. of San. Corps, Surgeon-General's Office, War Dept., Washington, D. C.

Yereance, Alex. W. 1st Lieut., Co. F, 305th Pioneer Engrs., Camp Lee, Petersburg, Va.

Yost, Howard McC. Capt., Engrs. U. S. R., 2030 F St., N. W., Washington, D. C.

Young, Frederick C. Capt., U. S. R.; Adjt., 114th Engrs., Camp Beauregard, La.

Young, George S. Capt., Engrs., U. S. R., Camp Lee, Petersburg, Va.

Young, Samuel M. Capt., Engrs., U. S. R.; Engr., New Orleans Assoc. of Commerce, 635 Common St., New Orleans, La.

Zinn, George A. Col., Corps of Engrs., U. S. A., 321 Custom House, Portland, Ore.

MEMBERSHIP

(From April 5th to May 2d, 1918)

ADDITIONS

MEMBERS		Date of Membership.
BURCH, GEORGE FRANCIS. Acting Bridge Engr., Div. of Highways, Dept. of Public Works and Bldgs., Springfield, Ill.		Mar. 12, 1918
BYRNE, EDWARD ABRAHAM. 34 Plaza St., Brooklyn, N. Y.		April 16, 1918
CASTLE, SAMUEL NORTHRUP. Commercial Engr., Gen. Elec. Co., 120 Broadway, New York City		April 16, 1918
CLARK, CHARLES HOMER. Pres., Clark Car Co., 1639 Oliver Bldg., Pittsburgh, Pa.		April 16, 1918
DAVIS, JAMES LYFORD. Dist. Highway Commr., State Highway Dept.; Engr., Bennington County Impvt. Assoc., Manchester Center, Vt.	Assoc. M. M.	May 4, 1904 Mar. 12, 1918
GREELEY, SAMUEL ARNOLD. Hydr. and San. Engr., 64 West Randolph St., Chicago, Ill.	Jun. Assoc. M. M.	Feb. 5, 1907 Mar. 4, 1913 April 17, 1918
HABERMEYER, GEORGE CONRAD. Engr., Illinois State Water Survey, 1103 Euclid St., Champaign, Ill.		April 16, 1918
HALL, WILLIAM HENRY. City Engr. and Director of Public Works, 2 Sherman Court, New Britain, Conn.	Assoc. M. M.	Oct. 4, 1910 Nov. 27, 1917
HUMPHREY, GILBERT EDWIN. Maj., Corps of Engrs., U. S. A.; Officer in Chg. of Engr. Depot, 1111 Calley Ave., Norfolk, Va.		Mar. 12, 1918
JONES, LEE MORGAN. City Engr., Port Arthur, Ont., Canada	Assoc. M. M.	July 2, 1913 Mar. 12, 1918
MACDONALD, CHARLES. County Supt. of Highways, Westchester County, Court House, White Plains, N. Y.	Jun. Assoc. M. M.	April 30, 1912 Oct. 1, 1913 April 17, 1918
MONTERO, JULIO DANIEL. Chf. Engr., Bureau of Roads and Bridges, P. O. Box 837, Havana, Cuba	Jun. Assoc. M. M.	Oct. 1, 1907 Feb. 28, 1911 Mar. 12, 1918
REIMANN, ROBERT. Asst. Engr. in Chg. of Surveys, B. & O. R. R., Relay, Md.	Jun. Assoc. M. M.	Oct. 3, 1905 Feb. 4, 1913 April 17, 1918
SCHUSLER, GEORGE WILLIAM. Div. Engr., Dept. of Public Works, 6201 Stanton Ave., Pittsburgh, Pa.		April 16, 1918
STEINMAN, DAVID BARNARD. Associate Engr., Waddell & Son, 35 Nassau St., New York City	Jun. Assoc. M. M.	Mar. 1, 1910 April 7, 1915 April 17, 1918

MEMBERS (*Continued*)

		Date of Membership.
Stevenson, William Lawrie. San. Engr., Dept. of Health and Sanitation, Emergency Fleet Corporation, U. S. Shipping Board, 3711 McKinley St., Chevy Chase, Md.	Assoc. M. M.	Oct. 2, 1907 April 17, 1918
Varney, William Wesley. Acting Harbor Engr., Baltimore City, 710 North Carey St., Baltimore, Md.		April 16, 1918
Wait, Bertrand Hinman. Dist. Engr., Portland Cement Assoc., 101 Park Ave., New York City	Assoc. M. M.	Jan. 2, 1912 April 17, 1918
Weed, Irving. 82 Lafayette Ave., Brooklyn, N. Y.		Mar. 12, 1918
White, Barclay. Pres., Barclay White & Co., 1713 Sansom St., Philadelphia, Pa.	Assoc. M. M.	Aug. 31, 1915 April 17, 1918
Woodle, Allan Sheldon, Jr. Engr. in Chg. of Constr., Baldwin Locomotive Works, Eddystone, Pa.	Assoc. M. M.	July 9, 1906 Mar. 12, 1918
Woodward, Sherman Melville. Prof. of Mechanics and Hydraulics, State Univ. of Iowa, Iowa City, Iowa		April 16, 1918

ASSOCIATE MEMBERS

Alger, Ralph Tisdale. Vice-Pres. and Treas., The Alger & Kraus Co. (Res., 1157 East 145th St.), Cleveland Ohio	Jun. Assoc. M.	June 24, 1914 April 16, 1918
Bainbridge, Charles Newton. With C., M. & St. P. Ry., Lombard, Ill.		Oct. 9, 1917
Bayly, Howard Paul. Prin. Asst. Engr., Saville & Claiborne, Inc.; Address, 102 South Boulevard, Richmond, Va.		April 16, 1918
Beam, Carl Eugene. Co. E, 316th Engrs., Camp Lewis, American Lake, Wash.		Mar. 12, 1918
Bloemker, Harold William. Engr. with J. S. Cornell & Sons, 1441 West Venango St., Philadelphia, Pa.	Jun. Assoc. M.	Oct. 31, 1911 April 16, 1918
Bres, Edward Sedley. 1st Lieut., U. S. R., 114th Engrs., Camp Beauregard, La.		Nov. 27, 1917
Britton, Lloyd C. Gen. Mgr., Alabama Central R. R., Jasper, Ala.		Mar. 12, 1918
Caughey, Robert Andrew. Asst. Prof. of Civ. Eng., Pennsylvania State Coll., 431 West Fairmount Ave., State College, Pa.		April 16, 1918
Chadwick, Hazleton Mirkil. Asst. Chf. Engr., The Valier-Montana Land & Water Co., Valier, Mont.		April 16, 1918
Connor, Edward Cowen. Engr., Vibrolithic Contr. Co., Inc., 4521 Highland Drive, Dallas, Tex.		Mar. 12, 1918

ASSOCIATE MEMBERS (*Continued*)		Date of Membership.
Craven, Aaron Sanford. Chf. Engr., Edwin H. Vare, 505 Independence Ave., Oak Lane, Philadelphia, Pa......		Mar. 12, 1918
Davis, Charles Eldridge. Chf. Draftsman, City of Spokane, City Engr.'s Office, Spokane, Wash........		April 16, 1918
Eden, Alfred William Alexander. Asst. Structural Engr., Westinghouse, Church, Kerr & Co., 37 Wall St., Room 900, New York City......................		Mar. 12, 1918
Eliot, William Mack. Office Engr., Houston Structural Steel Co., 1220 Harvard St., Houston Heights, Tex................	Jun. Assoc. M.	May 7, 1913 Mar. 12, 1918
Fairman, James Robert. Capt., Engrs. U. S. R., Fort Leavenworth, Kans.; Address, 4645 Aldrich Ave., South, Minneapolis, Minn......................		Oct. 9, 1917
Fisher, Ward Herbert. Mt. Comfort, Ind...............		Mar. 12, 1918
Flook, Lyman Russell. 1st Lieut., Ord. U. S. R., Govt. Nitrate Fixation Plant No. 1, Sheffield, Ala. (Res., 1309 Washtenaw Ave., Ann Arbor, Mich.).............	Jun. Assoc. M.	Dec. 3, 1913 Mar. 12, 1918
Garen, George Mason. Div. Engr., Norfolk Q. M. Terminal, Care, Col. M. A. Butler, Norfolk, Va........		April 16, 1918
Gauger, Paul Charles. Engr. and Supt., George J. Grant Constr. Co., 945 Osceola Ave., St. Paul, Minn.......		April 16, 1918
Goodwin, Ralph Edward. Estimator, Chile Exploration Co., 847 Boulevard East, Weehawken, N. J..................	Jun. Assoc. M.	Oct. 1, 1912 April 16, 1918
Grier, Alexander Monro. San Engr., E. I. du Pont de Nemours & Co., Wilmington, Del................		April 16, 1918
Hyman, Henry H. Mgr., Operation and Constr., Miami Elec. Light & Power Co., Box 875, Miami, Fla......		April 16, 1918
Lowrey, Samuel Macelroy. Engr., McLean Contr. Co. (Res., 317 East North Ave.), Baltimore, Md......................	Jun. Assoc. M.	Sept. 3, 1912 April 16, 1918
Milholland, Clarence Victor. Levelman, Transitman, and Field Engr., B. & O. R. R., 30 Citizens Bank Bldg., Parkersburg, W. Va......................		April 16, 1918
Montgomery, Julian. Chf. Office Engr., State Highway Dept., Austin, Tex..............................		April 16, 1918
Moore, Charles Audie. Vice-Pres., H. L. Stevens & Co., 910 South Michigan Ave., Chicago, Ill............		Mar. 12, 1918
Munkelt, Frederick Herman. Care, The Petroleum Iron Works Co. of Ohio, 613 Munsey Bldg., Washington, D. C.......	Jun. Assoc. M.	April 5, 1910 April 16, 1918
Sacks, Samuel Isaiah. Draftsman, Dept. of City Transit, 1755 North 31st St., Philadelphia, Pa.........................	Jun. Assoc. M.	Nov. 3, 1915 April 16, 1918

ASSOCIATE MEMBERS (*Continued*)

		Date of Membership.
Schoenberger, George Christian. Care, Board of State Engrs., 213 New Orleans Court Bldg., New Orleans, La.		Nov. 27, 1917
Serra, Julius Herschel. 28 Warwick Rd., Melrose Highlands, Mass.	Jun. Assoc. M.	Jan. 3, 1911 April 16, 1918
Shure, Austin Ferree. Res. Engr., Maryland State Roads Comm., Chestertown, Md.		Mar. 12, 1918
Stevenson, Charles Samuel. Civ. and Min. Engr., Pulaski Iron Co., Box 94, Eckman, W. Va.		April 16, 1918
Tebbs, Paul McGowan. Constr. Engr., Pennsylvania Highway Dept., 1845 Whitehall St., Harrisburg, Pa.		April 16, 1918
Tompkins, Robert Harry. 1st Lieut., 111th Engrs., Camp Bowie, Tex.		Mar. 12, 1918
Vanderhoof, Arnold Hines. U. S. Naval Radio Station, New Brunswick, N. J.		April 16, 1918
Walsh, Philip Joseph. Engr. and Gen. Supt., Road Constr., Kanawha County; Div. Engr., State Road Comm., Court House, Charleston-Kanawha, W. Va.	Jun. Assoc. M.	Oct. 10, 1916 April 16, 1918
Wells, James Parrish. Cons. Engr., 23 East Main St., Le Roy, N. Y.		Mar. 12, 1918
Williamson, John Kennedy. Pres. and Gen. Mgr., Porcupine Co., 1893 Park Ave., Bridgeport, Conn.		Mar. 12, 1918

JUNIORS

de Mahy, Stephen Greville. Land Surv. and Cons. Engr., St. Georges, Grenada	Nov. 27, 1917
Eaton, Herbert Nelson. 26 Dennison Ave., Framingham, Mass.	Mar. 12, 1918
Ebeling, Frederick William Carl. Archt., 13 Park Row, New York City	April 16, 1918
Ewin, James Perkins. Superv. Engr., Doullut & Williams, 1016 Hibernia Bank Bldg., New Orleans, La.	April 16, 1918
Hancock, John Seale. 610 Meridian St., Anderson, Ind.	Mar. 12, 1918
Lockhardt, William Francis. Sergeant, 1st Class, Sig. Corps; Room 810, Fletcher Savings and Trust Bldg., Indianapolis, Ind.	Oct. 9, 1917
Palmer, Herbert Martin. 312 West 102d St., New York City	April 16, 1918
Reinke, Edward Alexander. 1070 Twenty-first St., San Diego, Cal.	April 16, 1918

CHANGES OF ADDRESS

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ANDREWS, HORACE. 125 Lancaster St., Albany, N. Y.

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GOULD, WILLIAM TILLOTSON. Capt., Engrs. U. S. R., U. S. Military P. O. 705, Am. Exp. Forces, France.

HANSEN, PAUL. Capt., Engrs. U. S. R. (*Detached*), Am. Exp. Forces, France; Chf. Engr., State Dept. of Public Health, Springfield, Ill.

HARTS, WILLIAM WRIGHT. Brig.-Gen., G. H. Q., 1er Echelon, B. E. F., France.

HAZLEHURST, JAMES NISBET. Maj., Engrs. U. S. R., Gen. Staff, Gen. Headquarters, Am. Exp. Forces, France.

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INGALLS, OWEN LOVEJOY. Maj., Engrs., U. S. R., E. R. O. T. C., Camp Lee, Va.

JACKSON, DUGALD CALEB. Maj., Engrs., U. S. R.; Prof. of Elec. Eng., Mass. Inst. Tech.; Cons. Engr. (D. C. & Wm. B. Jackson), 248 Boylston St., Boston, Mass.

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LARRABEE, WILLIAM DOMINICK. Cons. Engr., Sherman, Cal.

LEISEN, THEODORE ALFRED. Maj., Q. M. C., U. S. R.; Const. Q. M., Camp Custer, Battle Creek, Mich.

LOUCKES, FRANK IRWIN. Capt., Engrs. U. S. R., Inland Water Transport Service, A. P. O. 702, Am. Exp. Forces, France.

MACARTNEY, MORTON. Engr., Porter Bros. Co., Security National Bank, Cheney, Wash.

MCKAY, HOOD. Pres., O. S. Richardson Coal Co., 15th Floor, Old Colony Bldg., Chicago, Ill.

MEMBERS (*Continued*)

McMeekin, Charles William. Maj., Engrs. U. S. R., Army War Coll., Washington, D. C.

Martin, Lewis M. Dist. Engr., Iowa State Highway Comm., Atlantic, Iowa.

Morrow, Jay Johnson. Col., Corps of Engrs. U. S. A., Commanding 4th Engrs., Am. Exp. Forces, France.

Myers, Edmund Trowbridge Dana, Jr. Maj., Ord. U. S. R.; Superv. Insp., Army Ordnance, 511 Fifth Ave., New York City.

Parks, Charles Wellman. Civ. Engr., U. S. N. (rank of Rear-Admiral); Chf. of Bureau of Yards and Docks, Navy Dept., Washington, D. C.

Pearl, Walter. Civ. and Hydr. Engr., 311 Wright and Callender Bldg., Los Angeles, Cal.

Perry, Charles Edwards. Capt., Engrs. U. S. R., Camp A. A. Humphreys, Va.

Phillips, Asa Emory. Superv. Engr., U. S. Army Activities, Port of Embarkation, Newport News, Va. (Res., 2117 Le Roy Pl., N. W., Washington, D. C.).

Phillips, Howard Crathorne. Chairman, West. Group, Eng. Committee, Presidents' Conference Committee, Federal Valuation of Railroads, 110 South Dearborn St., Chicago, Ill.

Phillips, William Hale. 232 Buckingham Pl., Philadelphia, Pa.

Phipps, Thomas Elmer. Capt., Engrs., U. S. R.; Officer in Chg. of Constr. and Repairs, Governors Island, New York City.

Pierce, Charles Henry. Dist. Engr., U. S. Geological Survey, Water Resources Branch, Custom House Bldg., Boston, Mass.

Pierce, Paul Leon. Lt.-Col., Ord. Dept., N. A., Care, C. P. O., U. S. Army P. O. 702, Am. Exp. Forces, France.

Potter, Henry Witbeck. 124 East Ashby Pl., San Antonio, Tex.

Quintus, John Charles. U. S. Asst. Engr., P. O. Drawer 960, Buffalo, N. Y.

Randall, Frank Alfred. 347 Madison Ave., Room 1207, New York City.

Ridgway, Robert. Engr., Subway Constr., Public Service Comm., First Dist., 49 Lafayette St., New York City.

Riggs, Thomas, Jr. Governor of Alaska, Juneau, Alaska.

Roberts, Shelby Saufley. Care, Office of Regional Director of Railroads, Healy Bldg., Atlanta, Ga.

Rostock, John Henry. Prin. Asst. Engr., U. S. Engr. Office, 44 Whitehall St., Room 1106, New York City.

Sanborn, Morton Franklin. Civ. and San. Engr., 339 West Union St., West Chester, Pa.

Schmidt, Max Eberhardt. Pres., Continuous Transit Securities Co. and Multiple Speed & Traction Co.; Cons. Engr., 68 William St., Room 1002, New York City.

Shaw, Franklin Dickinson. Capt., Engrs. U. S. R.; 101 North 7th St., Camden, N. J.

Shepley, Charles Rogers. Pres., Shepley Eng. Co. (Res., 638 Summit Ave.), St. Paul, Minn.

MEMBERS (*Continued*)

Smith, John Herman. P. O. Box 306, Nampa, Idaho.

Solomon, Gabriel Roberts. Maj., Engrs. U. S. R., Bldg. C, Room H307, Eng. Branch, Constr. Div., 7th and B Sts., Washington, D. C.; Civ., Structural and Hydr. Engr. (Solomon-Norcross Co.), 1622 Candler Bldg., Atlanta, Ga.

Thompson, Milton Theodore. Care, J. G. White Eng. Corporation, Nitrate No. 2, Sheffield, Ala.

Tinsley, Robert Bruce. Capt., Engrs. U. S. R., E. R. O. T. C., Camp Lee, Va.

Travell, Warren Bertram. With Edward F. Terry Mfg. Co., Grand Central Terminal Bldg., New York City.

Van Suetendael, Achille Octave. Capt., Engrs., U. S. R., 1438 U St., N. W., Washington, D. C.

Wallace, Harold Ulmer. Maj., Engrs. N. A.; Vice-Pres. and Gen. Mgr., The Western Light & Power Co., Boulder, Colo.

Warren, Horace Prettyman. Maj., 55th Engrs., N. A., Camp Custer, Battle Creek, Mich.

Waterbury, Leslie Abram. Office of Director, U. S. Govt. Explosives Plant "C", Nitro, W. Va.

Webster, Albert Lowry. Cons. Engr., 112 East 40th St., New York City.

Weir, Max Wakeman. 220 Broadway, New York City.

Wells, George Henry. Archt., 21 East 40th St., New York City.

Williams, Gardner Stewart. Cons. Engr., Cornwell Bldg., Ann Arbor, Mich.

Wilson, John. 910 North Stanton St., El Paso, Tex.

Woodard, Wilkie. Capt., U. S. R., Co. H, 35th Engrs., A. P. O. 735, Am. Exp. Forces, France; 1307 West 51st St., Los Angeles, Cal.

Wright, Joseph Bodine. 319 East 197th St., New York City.

Young, Samuel McCain. Capt., Engrs., U. S. R.; Engr., New Orleans Assoc. of Commerce, 635 Common St., New Orleans, La.

ASSOCIATE MEMBERS

Alden, Langford Taylor. Eléve Aspirant, 32me Artillerie (French Army), Care, Morgan, Harjes Cie., Boulevard Hausseman, Paris, France.

Allison, Leonidas Metcalfe. 810 Commonwealth Bldg., Philadelphia, Pa.

Armitage, George Washington. Capt., Q. M. C. U. S. R., Care, Quartermaster, Port of Embarkation, Hoboken, N. J.

Ashton, Raymond. U. S. Army School of Military Aeronautics, Cambridge, Mass.

Ayres, John Henry. Capt., U. S. R., Co. D, 42d Engrs., Camp American University, Washington, D. C.

Barber, Justin Frederic. Sergeant, Co. M, 23d Engrs., Am. Exp. Forces, France; Address, 1515 Mozart St., Alameda, Cal.

Barber, Norman Nathaniel. Capt., N. A., 16th Engrs., Am. Exp. Forces, France.

ASSOCIATE MEMBERS (*Continued*)

BARNES, HARRY. 1901 Clay St., Fresno, Cal.

BAXTER, ORA GROVER. Capt., U. S. R., Co. C, 601st Engrs., Camp Glen Burnie, Md.; Address, 4312 Fairview Rd., Hillcrest, Pulaski Heights, Little Rock, Ark.

BLEE, CLARENCE EARL. Care, C. O. P. Co., Klamath Falls, Ore.

BLOSSER, EMMET CHANDLER. Div. Engr., State Highway Dept., 2419 Indianola Ave., Columbus, Ohio.

BORCHERS, PERRY ELMER. Supt. of Constr., Indian Service at Large, Towaoc, Colo.

BOWLBY, HENRY LEE. Maj., 43d Engrs., N. A., Headquarters, Camp American University, Washington, D. C.

BOWMAN, RALPH MCLANE. Care, Lackawanna Bridge Co., Buffalo, N. Y.

BRADBURY, RICHARD ROBERTSON. 612 Pine Ave., Niagara Falls, N. Y.

BROWN, ROBERT HUSE. Capt., San Corps, N. A., Office, Surgeon General, U. S. A., Washington, D. C.

BROWN, ROBERT KING. Div. Engr., L. A. & S. L. R. R., 228 Union Station, Salt Lake City, Utah.

BRUSH, CARL FLETCHER. Capt., Engrs. U. S. R., U. S. M. P. O. 716, Am. Exp. Forces, France.

CASE, CHARLES ANDREW. 1st Lieut., U. S. R., 314th Engrs., Camp Funston, Kans.; 833 Fifteenth St., Charleston, Ill.

CHASE, CLIFFORD EARL. Capt., U. S. R., Co. A, 4th Engrs., Camp Greene, Charlotte, N. C.

CHURCHILL, ROBERT CARR. Lieut., Co. D, 25th Engrs., Am. Exp. Forces, France; 813 Orchard Hill, Roanoke, Va.

CLARK, ROY ROSS. Structural Engr., Y. M. C. A. Overseas Force for Erecting Bldgs. in France, A. P. O. 705, Am. Exp. Forces, France; Address, 1223 Clinton St., Portland, Ore.

CLARKE, WILLIAM DEXTER. Capt., U. S. R., 23d Engrs. (Highway), Am. Exp. Forces, France.

COLEMAN, EUGENE HUNTER. Capt., U. S. R., 312th Engrs., 87th Div., N. A., Camp Pike, Ark.

COMLY, JAMES RETZER. 1st Lieut., U. S. R., 55th Engrs., Camp Custer, Battle Creek, Mich.; 4105 Falcon St., San Diego, Cal.

COOKE, FREDERICK HOSMER. Civ. Engr. U. S. N. (rank of Lt.-Commander), Care, U. S. Navy High-Power Radio Detachment, Care, Postmaster, New York City.

CORNELL, JOHN WESLEY. Capt., Q. M. C., N. A., Constr. Div., 7th and B Sts., Washington, D. C.

CROCKER, JAMES ROGER. Capt., U. S. R., Co. F, 106th Engrs., Camp Wheeler, Macon, Ga. (Res., 202 West 79th St., New York City).

DRAYTON, NEWBOLD. Corporal, Battery D, 108th F. A., 53d Artillery Brigade, 28th Div.; Address, 5 South 21st St., Philadelphia, Pa.

DYKEMAN, CONRAD FRANCIS. 1st Lieut., U. S. R., 116th Engrs., P. O. 733, Am. Exp. Forces, France (Res., 657 Jefferson Ave., Brooklyn, N. Y.).

ASSOCIATE MEMBERS (*Continued*)

EAGER, VERNON MILTON. Capt., Q. M. C., N. A., Care, Const. Q. M., Camp Raritan, Metuchen, N. J.

EDDY, HAROLD MANSFIELD. Asst. Civ. Engr., U. S. N. R. F. (rank of Lieut. (Junior Grade)), 4225 Grant Circle, Washington, D. C.

FARRIN, JAMES MOORE. Capt., U. S. R.; Adjt., 6th Bn., 20th Engrs., Am. Exp. Forces, France.

FIFER, ALOIS JOHN JOSEPH. Cons. Engr., Bishopsgate House, 80 Bishopsgate, London, E. C. 2, England.

FISHER, WILBUR HOWARD. Asst. Engr., U. S. Reclamation Service, Box 201 A, Mitchell, Nebr.

FISK, CLINTON HINCKLEY. Maj., Engrs. U. S. R., Constr. Div.; 5142 Westminster Pl., St. Louis, Mo.

FITZPATRICK, FRANCIS JAMES. Capt., U. S. R., Co. C (Service Bn.), 508th Engrs., Am. Exp. Forces, France.

FITZSIMONS, WAVELAND SINCLAIR. Asst. Engr., U. S. Engr. Dept., Care, U. S. Engr. Office, Savannah, Ga.

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	Date of Resignation.
May, DeCourcy	April 16, 1918

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Hayes, Morgan Dodge	April 16, 1918
Jonson, Ernst Fredrik	April 16, 1918
Krause, Louis Gustav	April 16, 1918
Marsh, Francis Beal	April 16, 1918

JUNIORS

Bacon, Ethelbert	April 16, 1918
Cartwright, Henry Hart	April 16, 1918

DEATHS

DAVENPORT, JAMES AUBREY. Elected Member, April 5th, 1905; died March 15th, 1918.

HAGAR, EDWARD MCKIM. Elected Associate Member, February 6th, 1901; died January 18th, 1918.

HUGGINS, WILLIAM. Elected Member, February 7th, 1906; died February 21st, 1918.

LAMONT, CLARENCE BOOTH. Elected Associate Member, May 4th, 1909; Member, June 24th, 1914; died March 21st, 1918.

LOWE, JESSE. Elected Member, October 2d, 1895; died April 17th, 1918.

MARPLE, WILLIAM MCKELVEY. Elected Member, June 4th, 1890; died March 20th, 1918.

MUENSCHER, EMORY WASHBURN. Elected Member, July 5th, 1893; date of death unknown.

ROBERTSON, MARSHALL POPE. Elected Associate Member, March 5th, 1902; Member, September 4th, 1906; died November, 1917.

THOMPSON, CLARK WALLACE. Elected Junior, March 5th, 1890; Associate Member, July 3d, 1895; died March 16th, 1918.

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(4) *Journal,* Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Transactions,* Can. Soc. C. E., Montreal, Que., Canada.
(6) *Journal,* Am. Inst. of Archts., Washington, D. C., 50c.
(8) *Stevens Indicator,* Hoboken, N. J., 50c.
(9) *Industrial Management,* New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, 432 Fourth Ave., New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News-Record,* New York City, 15c.
(15) *Railway Age,* New York City, 15c.
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(22) *Iron and Coal Trades Review,* London, England, 6d.
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MAY, 1918

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PAPERS AND DISCUSSIONS

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IMPROVING ARCH ACTION IN ARCH DAMS

By L. R. Jorgensen, M. Am. Soc. C. E.

To be Presented June 5th, 1918.

Synopsis.

In this paper the reasons for arch (rib) shortening, and the resulting opening up of the contraction joints on unloaded arch dams, are first discussed.

Crown deflections, plotted from measurements taken during a series of years on an arch dam, are given and discussed. The deflection curves indicate very plainly the great influence of temperature changes on the deformation of arch dams, and therefore, also, on the stresses in the building material (concrete) used.

It is shown how the practical arch deviates from the intended or theoretical arch; and, finally, a method is outlined for pressure grouting the spaces between adjacent walls of the contraction joints along the arch, whereby a key-stone, so to speak, is inserted under pressure into each contraction crack. This grouting is intended to be done at the end of a cold season, some time after the dam has been completed, and with the reservoir empty, or as nearly empty as possible.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

The grouting puts initial compression into the arch, whereby the shearing and cantilever stresses can be cut down, perhaps to half the value they otherwise would have.

The water-tightness of the structure is also improved by this grouting operation.

INTRODUCTION.

The writer has been connected with arch dam design and construction for some years, and has taken particular interest in watching the behavior of several existing dams, especially of the arch type.

The fact that arch dams, and mainly those of heavy sectional area, do not develop arch action before considerable load has been applied to them, is generally known, but, to a great extent, has not been especially considered in their design.

At present, working stresses of about 25 tons per sq. ft., as used in ordinary dam practice, are sufficiently low to produce a safe structure, even in spite of the fact that the formulas used for the design do not consider everything.

It is obvious, however, that if the practical arch could be constructed in such a way as to coincide more nearly with the ideal arch—that is, one which acts as an arch from the very start, and in which the load is mainly carried by pure arch action—a still safer structure would result. Higher unit stresses than are now common could be used with safety, if arch action could be made more definite from the start. The factor of safety to be used would depend on the importance of the particular structure in each case.

The two main reasons for the phenomenon that an arch dam does not act as an arch before considerable load has been thrown on it are, as is well known: First, the shortening of the arch rib due to shrinkage; and, second, because the arch is fastened to the foundation.

The shortening of the arch rib is caused by the natural shrinkage of the concrete as it sets, the dissipation of the chemical heat, the permanent set after the reservoir has filled once, and the fact that dams are of necessity almost always built during the season of highest temperature.

This shortening of the arch rib is plainly visible on dams provided with contraction joints. With an empty reservoir, during cold weather, these joints will have opened up from ¼ in. to perhaps as much as ⅜ in., where spaced, say, 60 ft. apart. If not provided with contraction joints, a dam of heavy cross-sectional area will undoubtedly show cracks at more or less regular intervals from 40 to 80 ft. apart. A dam of slim cross-sectional area may not always crack, as it is somewhat flexible, and the crown can often be pulled in a down-stream direction without developing excessive tension in the arch.

In cases where the contraction joints have opened up, the water level in the reservoir will have to rise a certain distance in order to throw sufficient load on the structure to force the dam, acting as a cantilever, to deflect in a down-stream direction, before the voussoirs—that is, the bodies between the contraction joints—come into contact with one and another. Only from that moment does the remainder of the water load divide up between the arch, the curved beam, and the cantilever.

In the case where the arch has not cracked, although under the influence of tensile stresses, the water level in the reservoir will have to rise until this tension has been compensated for by pressing back the cantilever. The remainder of the water load is then divided up between the arch, the curved beam, and the cantilever, according to their relative capacities for sustaining load.

The fact that the arch is fastened to the foundation prevents any considerable arch action from taking place at or near the latter; this, however, is not detrimental to the safety of the structure, such as would be the shortening of the arch due to shrinkage. The load on the lower portion of the arch causes shearing stresses in the concrete next to the rock and for some distance above and below. These shearing stresses, in turn, cause an elastic deformation, of both the dam and the rock foundation, to take place in a down-stream direction, especially at the crown of the arch, where the movement in that direction is the greatest. Ordinarily, the rock bottom has a higher modulus of elasticity than the concrete; it is well supported laterally from all sides, and therefore offers greater resistance to this movement (perhaps three times) than the concrete, but there is nothing to warrant the assumption that the rock bottom is immovable, and measurements also seem to indicate that it is not although measurements of such movements are very difficult to make correctly, as they are so small in this region.

A trial calculation will ordinarily indicate very low unit shearing stresses at the foundation, even assuming that shear alone carried all the load on, say, the lower fifth of the dam.

The unit shearing stresses, in most cases (perhaps in all cases), will be less than the unit weight multiplied by the coefficient of friction; but, in any case, the weight of the structure will exert considerable unit compression perpendicular to the horizontal plane of shear, and thereby improve the ability of the concrete to withstand shearing stresses along horizontal planes.

DEFLECTION CURVES.

The curves shown on Figs. 1 and 2 are typical for the deflection of the crown of an arch dam due to different water loads and different temperatures of the dam body. The curves are plotted from measurements taken on the Salmon Creek Dam, near Juneau, Alaska. This dam, Fig. 4, is of the constant-angle arch type, 168 ft. high, with a crest span of 550 ft.*

Fig. 3 shows the maximum cross-section at the crown. On this cross-section is indicated a number of horizontal steel rods embedded in the masonry, 20 ft. apart. These steel rods are provided with copper points on the down-stream end for weather-proofing purposes. The different readings were obtained by sighting these points through a transit and determining their position in regard to fixed bench-marks.

It is very difficult to measure the deformation close to, or at, the foundation. It is so small that a transit reading would not be accurate enough, and if a stationary measuring apparatus was arranged on the ground, down stream from the dam, it would have to be at least 50 ft. distant in order to be on ground which does not take part in any movement caused by the load on the dam. The measuring tape or rod then becomes so long that all measurements taken must be compensated for temperature changes, and even a small error in such calculations or estimates will be sufficient to make this method of doubtful value. The best thing to do seems to be to extend downward, in a uniform direction, the curve obtained from observations at higher elevations.

The measurements on the Salmon Creek Dam were commenced on October 8th, 1914, when the reservoir was filling for the first time,

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* A complete description of this dam may be found in *Transactions*, Am. Soc. C. E., Vol. LXXVIII (1915), p. 702.

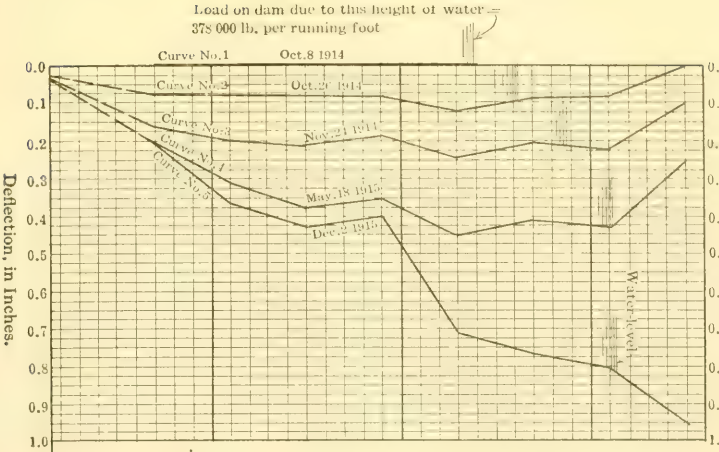


FIG. 1.

DEFLECTIONS OF SALMON CREEK DAM.

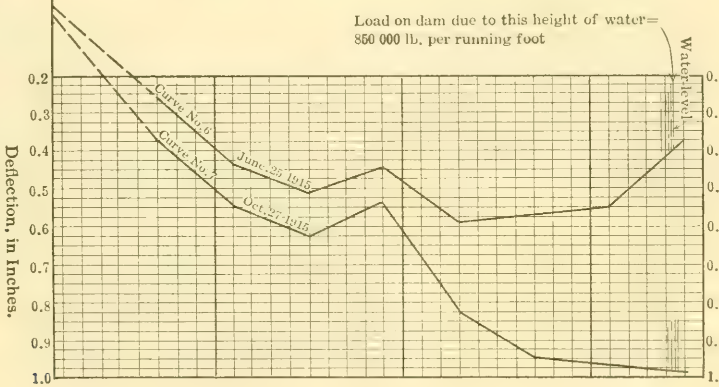


FIG. 2.

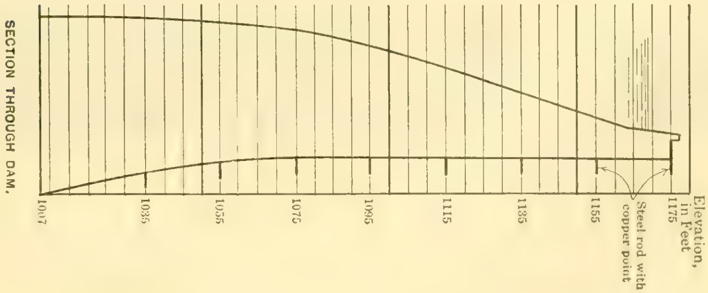


FIG. 3.

and the position of all the copper points on that date is taken as zero for all curves shown on Figs. 1 and 2. The actual zero will lie a little to the left; it may be some time before the water will be low enough to determine it by measurements.

The load due to the water level shown for Curve No. 1 was sufficient to keep the contraction joints (only two) closed.

There is not much that need be explained about the results of the first and second deflection measurements—those taken on October 26th, and November 24th, 1914. The water kept rising, deflecting the crown in a down-stream direction, about as might have been expected. The fourth measurement, Curve No. 4, taken on May 18th, 1915, begins to show some peculiarity about this dam, that is, the knee in the deflection curve at Elevation 1095, which is still more apparent on the three following curves. This peculiarity is caused by construction features which must be known to be appreciated. As it was necessary to stop construction work late in the fall of 1913 at about this elevation, the zone of the dam in this vicinity was built during the coldest portion of the fall and the coldest portion of the following spring. The total shrinkage of the concrete in this zone, therefore, has been less than the average, and the arch, therefore, takes a greater proportion of the total load than it does either above or below; in fact, some load is transferred through the vertical beam (the cantilever) to this zone from both above and below. Such transference of load also takes place through the vertical beam at the crest, as shown by Curve No. 4, but this would be expected in any case.

Curve No. 5 shows considerably more excess deformation of the dam than Curve No. 4, although the water load is only slightly higher, but Curve No. 5 was plotted from measurements taken on December 2d, 1915, at a time when the days had been short and cold for some time, compared with the long, warm days around May 18th (Curve No. 4). Curve No. 5 also indicates that the outside temperature has been lower than that of the water and the dam body below the water level for some time, as the portion of the dam above the water level is forced down stream to a greater extent than the lower loaded portion as a result of the greater shortening of the arch (rib) in the upper region, produced by a lower temperature in the upper exposed portion of the dam.

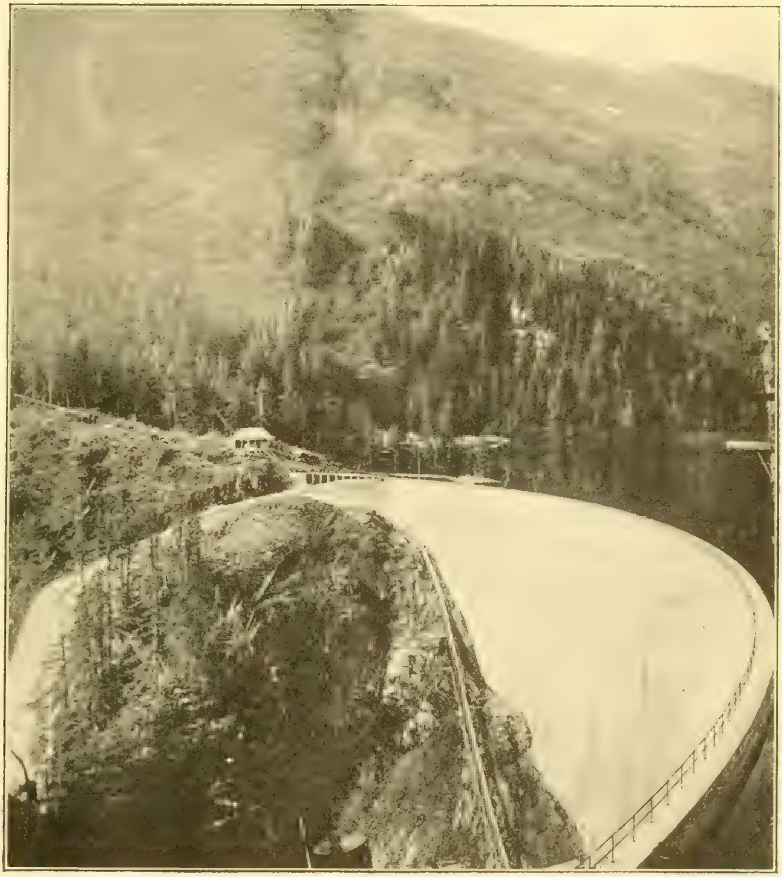


FIG. 4.—SALMON CREEK DAM, NEAR JUNEAU, ALASKA. 168 FEET HIGH.

Curves Nos. 6 and 7 give an idea of the magnitude of the deformation due to temperature changes alone. The water load is the same in both cases—that due to reservoir full—but the average temperature of the dam body was high when the measurements for Curve No. 6 were taken, on June 25th, 1915, and low when the measurements for Curve No. 7 were taken, on October 27th, 1917. The days, of course, are still shorter and colder in January (Juneau, Alaska) than in the latter part of October, but October 27th was the last day the reservoir was full to the spillway crest.

Both curves are of the shape expected, except for the knee at Elevation 1095, but low temperatures at the time of construction were responsible for that, as already explained.

That the upper end of Curve No. 6 turns in an up-stream direction, the same as on Curves Nos. 2, 3, and 4, is only logical. All dams—and this is no exception—are provided with an excess of material at the crest, and therefore the stresses and the resulting deformation must be less in this than in lower zones; besides, for Curves Nos. 4 and 6, the outside temperature, and therefore, also, the temperature of the dam body, especially at the crest, was higher than that of the water on May 18th and on June 25th.

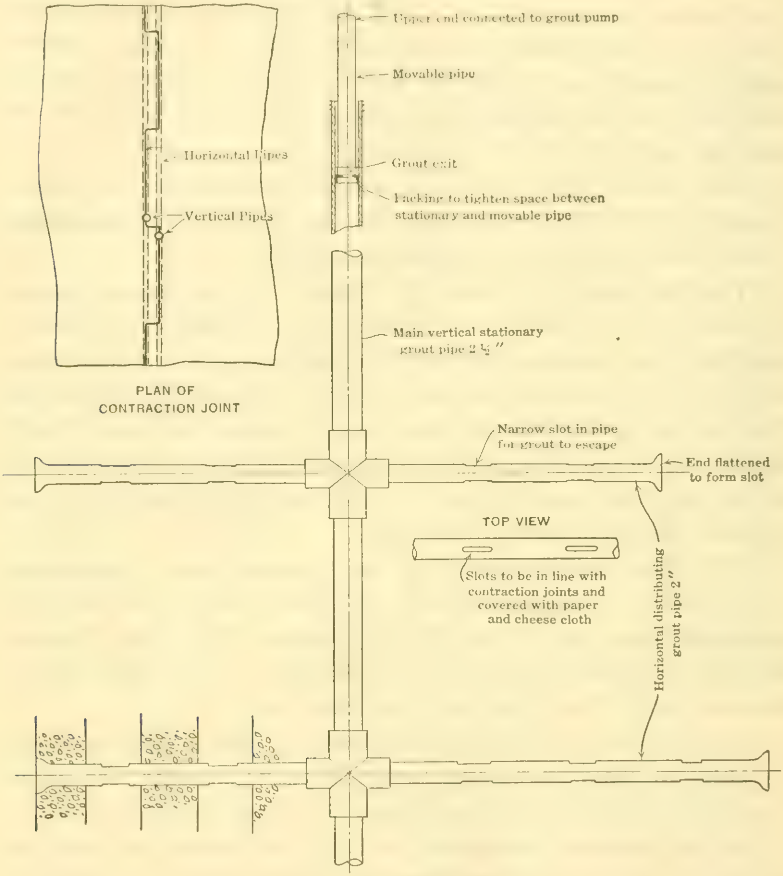
This higher temperature of the crest portion tends to accentuate the pointing of the upper portion of Curves Nos. 4 and 6 in an up-stream direction. Curve No. 7 (October 27th, 1915) indicates the effect of lower temperatures of the crest portion, than that of the water and of lower portions of the dam body.

The horizontal scale of these curves is exaggerated 1 200 times, in order to show the results more plainly. In reality, the curves are smooth, although the irregularities, as shown, are present.

In the foregoing description, some of the actions and behaviors of arch dams have been explained in detail. In the following the method of eliminating some of the undesirable features and making the structure act more like a theoretical arch, than otherwise possible, will be outlined.

By a simple system of iron pipes (shown in Figs. 5 to 8), distributed on the face of the contraction joints, and provided with slots at certain intervals, it is possible to deliver cement grout under pressure into the space (from $\frac{1}{4}$ to $\frac{3}{8}$ in. wide) between adjacent walls of the contraction joints, and put initial axial compression into the whole structure, thereby making it act like a solid arch.

At the same time, this grouting will greatly improve the water-tightness of the dam.


Horizontal Pipes
Vertical Pipes
PLAN OF CONTRACTION JOINT
Upper end connected to grout pump
Movable pipe
Grout exit
Packing to tighten space between stationary and movable pipe
Main vertical stationary grout pipe 2½″
Narrow slot in pipe for grout to escape
End flattened to form slot
TOP VIEW
Slots to be in line with contraction joints and covered with paper and cheese cloth
Horizontal distributing grout pipe 2″

ARRANGEMENT OF PIPES FOR GROUTING.

FIG. 5.

It is well known that contraction joints, even of the most efficient design, cannot be expected to be entirely water-tight. The leakage through such joints on large structures may easily amount to from 10 000 to 20 000 gal. daily, and has amounted to as much as 450 000 gal. daily.* This can be eliminated by grouting the joints under pressure; still, the main purpose of this grouting is to compel the arch dam to act as an arch from the very moment the water begins to fill the reservoir.

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* *Transactions*, Am. Soc. C. E., Vol. LXXXI (1917), p. 1064.

Forcing the grout into the contraction joints, and keeping it there under pressure until it has set, presses the crown of the arch in an up-stream direction, and puts shear on the foundation in the opposite direction to that due to the water load. It seems logical, therefore, to use such a grout pressure as will force the crown up stream half the total amount of the deflection resulting from a full reservoir. In this way the maximum shearing stresses are reduced by one-half (reservoir full), the maximum cantilever stresses are reduced by one-half, and, when fully loaded, the arch compression should then be as nearly as possible in accordance with the values obtained from the simple formula:

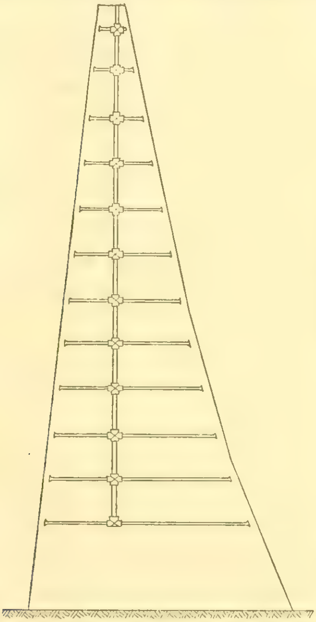


Fig. 6.

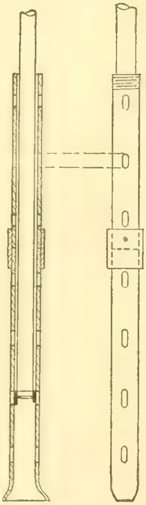


Fig. 7.

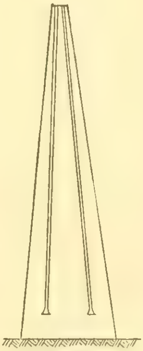


Fig. 8.

$$\text{Unit compression} = \frac{\text{Unit water pressure} \times \text{up-stream radius}}{\text{Thickness of section}}$$

A check on the necessary grout pressure can be obtained by sighting across the crown of the arch with a transit, after first establishing the necessary bench-marks.

Great refinement in choice of final grout pressure, however, cannot be counted on, and is not essential. Considering the great influence of the temperature on the total deflection of the arch structure, as can be seen from the curves, especially Curves Nos. 6 and 7, it is necessary to use some judgment as to what the grout pressure should be in each case.

As a general rule, it can be stated that the grouting ought to be accomplished at a time when the structure is cold, and when the joints, therefore, have opened to their maximum extent, permitting easy access for the flow to all parts of thin grout (1 cement to 7 water to start with and thicker to finish). A large dam will generally have the least volume during March, and, therefore, the contraction joints will have opened up a maximum during this time, if the reservoir is empty.

When applying the grout pressure at such a time, it should be kept in mind that the dam body is larger at any other time, due to an increase in temperature, and that, with the cracks closed, the compression per square inch of contact surface will be increased as the temperature of the dam body increases.

Thus far only arch dams have been mentioned, but it would not require much explanation to show the advantage of tight grouted contraction joints on straight gravity dams also.

Grouting the contraction joints under pressure on straight dams throws longitudinal compression on the structure, and enables it to act as a beam held at both ends, at least until the initial compression has been overcome by the beam tension. A trial calculation will prove that the factor of safety has been greatly improved, especially at the lower levels, unless the dam is very long.

The grouting of the joints naturally improves the water-tightness of the dam, and, for this benefit alone, it is worth its cost. Judging from the results of analysis of leakage water through concrete dams, there are good reasons for assuming that a tight dam is going to remain safe for a longer time than a leaky one, although the writer is not attempting to predict the probable natural life of any dam.

A straight dam which has its contraction joints grouted under pressure during the cold season, will automatically have this pressure increased during the warm season, at the rate of about 11 lb. per sq. in. for each degree of rise of temperature of the concrete of 1°

Fahr., as this material tries to expand and cannot. This, of course, should be allowed for, when selecting the grouting pressure for a straight dam. There could be no objection, however, to having a longitudinal compression of, say, from 200 to 300 lb. per sq. in., or even more, on the concrete during the warm season.

A typical grout piping arrangement for a rather large dam section is shown by Figs. 5 and 6.

On the plan of the contraction joint on Fig. 5 there are two vertical feed pipes which are desirable on a joint of the kind shown. Each vertical pipe feeds a system of horizontal pipes arranged at different levels. These horizontal pipes are provided with slots wherever they cross the open space of a joint (Fig. 5). When the pipes are put in place, these slots are covered with paper and cheesecloth to prevent the concrete from entering the pipes from the outside and blocking them. Later, when the contraction joints open, this covering will either adhere to the concrete, or the grout pressure will burst it open.

The pipes cannot be recovered, but will remain forever buried in the dam. They are necessary, however, in order to keep the grout in a liquid condition from the time it leaves the pump until it passes through a slot very close to the desired point of deposit. The iron walls of the pipes do not absorb any of the water in the grout; the absorption, however, commences as soon as the grout leaves the exit slot in the pipe and comes in contact with the concrete walls of the joint. Therefore, this outside grout sets first and shrinks, to a large extent. The grout in the pipe system, being fluid for a long time, is able to follow up the shrinkage and fill out the cavities and keep the joint under pressure until the filler has solidified, in from ½ to 1 hour or more.

To avoid air pockets as much as possible, and otherwise to insure uniform work, the grouting should proceed from the bottom up; therefore a second, and movable, pipe is inserted in the stationary vertical pipe at the time grouting is to be done, as indicated in Fig. 5.

When starting to grout, one end of this movable pipe is to be at the bottom of the vertical pipe, the upper end being connected to the grout pump by a flexible connection. Grout is forced through the movable pipe and flows through the lower Tee, the lower horizontal pipes, and the slots in them, out into the space between the walls of the contraction joints, and rises vertically.

Before grouting commences the down-stream end of the contraction joints should be caulked (with lead wool) except for small stretches left open for exploration purposes. These are closed when the grout starts to flow out of them. The up-stream end of the contraction joints are generally provided with copper plates or other kinds of effective stops.

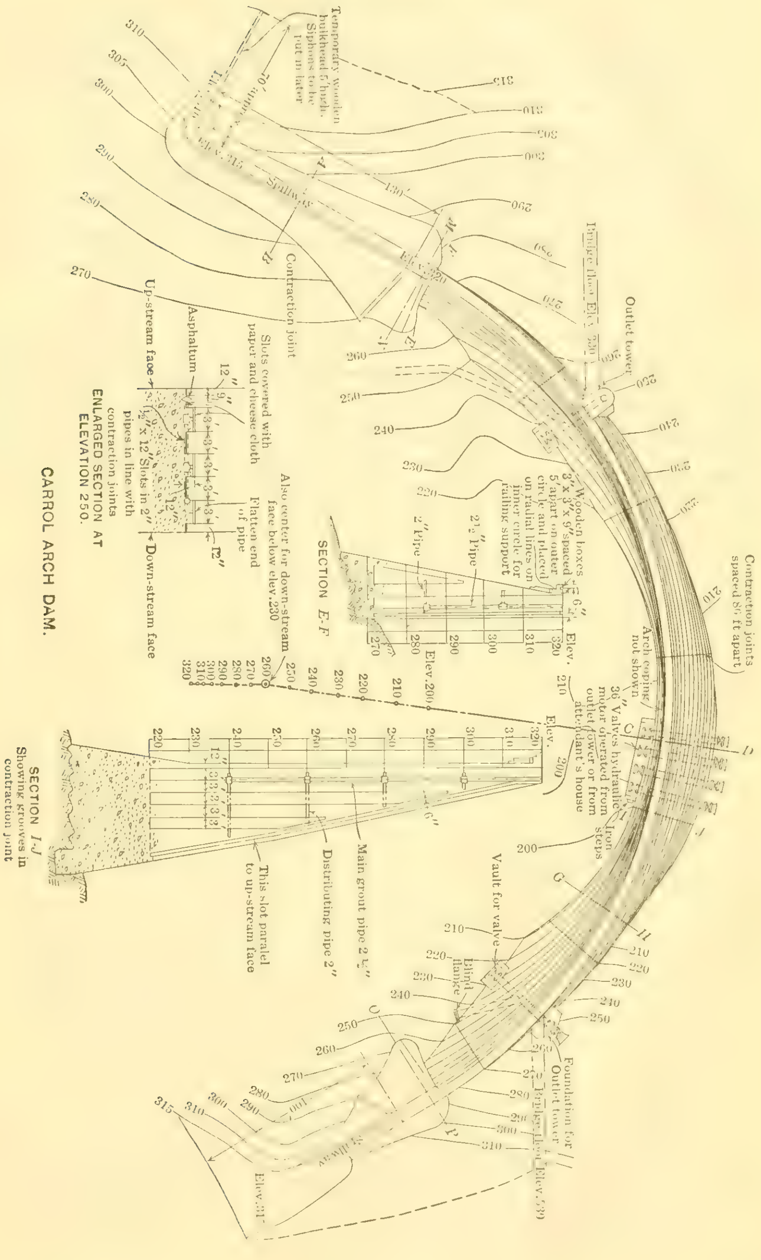
When the grout has reached the second story of horizontal pipes, or nearly to it, the movable pipe is raised so that the lower end is just above the Tee connection leading to those pipes. Grout is then forced into them, and, proceeding in the same manner as previously described, the crest is eventually reached. Then, finally, the pressure is kept on until the filler has thoroughly set. It is the grout pressure used on the last, or preferably on the last two joints, spaced one-third of the arch length apart, that determines the initial arch compression, and therefore on these the greatest care should be exercised.

If a dam is so large and high that it takes two or three seasons to build it, it is advisable to grout the lower third of the height at the end of the cold season, before the construction of the dam is continued; otherwise, the lateral expansion (Poisson's ratio), due to the weight of material on top, will tend to close the contraction joints. These spaces will always be narrower close to the foundation than higher up, due to shearing stresses, developed by shrinkage in the concrete close to the rock bottom, tending to prevent complete contraction.

When grouted during cold weather, an arch dam will always be under the influence of compressive stresses, and any knee in the deflection curve, due to inequalities in temperature during the construction period, will be flattened out. All told, the arch dam will act more nearly as intended, carry the load as calculated, and be more water-tight than without the grouting of the contraction joints. A straight dam will have its factor of safety increased, due to the positive beam action, and also be more water-tight.

Figs. 7 and 8 illustrate a simple arrangement of grout piping for the contraction joints of a small dam.

Fig. 9 shows what is regarded as the best arrangement of grout piping for the contraction joints of a dam of medium size (the Carroll Arch Dam). The location of these joints is indicated (not in detail, however) on this figure, which also shows the complete arch, together


Temporary wooden bulkhead 5' high. Siphons to be put in later
70' approx.
Elev. 315
Spillway
130'
A
B
Contraction joint
Bridge floor Elev. 330
Outlet tower
Slots covered with paper and cheese cloth
Asphaltum
Up-stream face
12"
9"
3'
1½"x 12" Slots in 2" pipes in line with contraction joints
Down-stream face
ENLARGED SECTION AT ELEVATION 250.
Wooden boxes 3"x 3"x 9" spaced 5' apart on outer circle and placed on radial lines on inner circle for railing support
2½" Pipe
2" Pipe
SECTION E-F
Flatten end of pipe
Also center for down-stream face below elev. 230
Elev.
Elev. 200
Contraction joints spaced 86 ft apart
Arch coping not shown
36" Valves hydraulic motor operated from outlet tower or from attendant's house
Iron steps
Main grout pipe 2½"
Distributing pipe 2"
This slot paralel to up-stream face
SECTION I-J
Showing grooves in contraction joint
Vault for valve
Blind flange
Foundation for Outlet tower
Bridge floor Elev. 330
Elev. 315
Spillway
C
D
G
H
I
J
E
F
200
210
220
230
240
250
260
270
280
290
300
305
310
315
320

CARROL ARCH DAM.

FIG. 9.

with its tangent spillways. The enlarged section at Elevation 250 shows the details of a typical contraction joint. Only one vertical pipe is provided, and from this several stories of horizontal pipes reach all parts of the face of the joints.

The longitudinal faces of the individual recesses, making up the contraction joint, are to be made slightly tapering, so as to make sliding more certain. It should be kept in mind, however, that parallel faces will produce the greatest water-tightness, and, therefore, the tapering should be very slight, only enough to take care of construction irregularities.

The deflection curves of Figs. 1 and 2 were made under the direction of Mr. H. L. Wellenberg, formerly Chief Engineer of the Alaska Gastinau Mining Company, Juneau, Alaska. Measurements on other dams have been made, but those given are characteristic of the deflection of the crown of an arch dam, due to changes in load and temperature.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications.

EMERGENCY CONSTRUCTION WORK DUE TO WAR CONDITIONS, WITH ESPECIAL REFERENCE TO THE CONSTRUCTION DIVISION OF THE ARMY*

By George W. Fuller, M. Am. Soc. C. E.

In an address which deals with emergency construction work, attention focuses at once on the fact that this week marked the first anniversary of the entrance of our country into the great world war. During the past year emergency conditions with respect to the military establishment called for an enormous amount of construction work. The mere magnitude of the undertakings is impressive. It is worth while to point out briefly in what measure the United States, practically unprepared for war, found itself suddenly facing the stress of military activities.

In the summer of 1917 the Secretary of the Treasury, for the guidance of Congressional Committees, prepared estimates of expenditures for the current fiscal year, with major items as given in Table 1.

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* This address is based on an informal talk on this subject, illustrated with more than forty lantern slides, before the meeting of the Society on April 3d, 1918, at the conclusion of which Mr. Fuller was requested, by a vote of the meeting, to prepare the material presented for publication in *Proceedings*.

Authority to print this address was given in the following permit:

"WAR DEPARTMENT
"Office of Construction Division
"Washington.

"May 4, 1918.

"From: Officer in Charge of Construction Division.
"To: Mr. George W. Fuller, 170 Broadway, New York, N. Y.
"Subject: Address before The American Society of Civil Engineers.

"1. This office has reviewed manuscript report of your address delivered before the American Society of Civil Engineers on April 3rd, and it is agreeable that this should be published in the regular proceedings of the Society.

"R. C. Marshall, Jr.,
"Colonel, Quartermaster Corps, N. A.,
"In Charge of Construction Division."

TABLE 1.—OFFICIAL ESTIMATES OF GOVERNMENT EXPENDITURES FOR THE FISCAL YEAR ENDING JUNE 30TH, 1918.

War Department:		
Salaries and expenses	$9 318 315.41	
Quartermaster Corps	3 633 360 930.75	
Ordnance Department	3 154 959 151.00	
Medical Department	130 746 547.73	
Signal Service, including Aviation	625 000 000.00	
Engineer Department, Rivers and Harbors	289 862 676.06	
National Guard	10 000 000.00	
Military Academy, and Miscellaneous Military and Civil items	10 992 863.00	$7 864 240 483.95
Navy Department:		
Salaries and expenses	$1 994 000.00	
Aviation	51 000 000.00	
Enlistment, Transportation and Training	15 500 000.00	
Emergency Fund	165 550 000.00	
Ordnance	261 000 000.00	
Public Works	62 600 000.00	
Expenses of the Fleet	130 000 000.00	
Medicine and Surgery	6 700 000.00	
Pay of the Navy	124 000 000.00	
Supplies, Fuel, etc	52 800 000.00	
Naval Academy	1 000 000.00	
Marine Corps	35 000 000.00	
Naval Militia	2 040 000.00	
Increase of the Navy	286 566 000.00	
Miscellaneous	4 250 000.00	1 200 000 000.00
Independent Offices:		
United States Shipping Board	$799 517 500.00	
Council of National Defense	500 000.00	800 017 500.00
		$9 064 240 483.95

In considering the magnitude of these estimated expenditures of the United States Government, it is well to compare the aggregate sum with the total ordinary annual disbursements of the Government for running all its departments, and for interest on the public debt for earlier fiscal years. Mention may be made of some of these annual amounts, prior to the entrance of our country into the European war, as follows:

1902.	1907.	1912.	1917.
$468 788 705.	$544 075 746.	$652 985 768.	$1 041 635 116.

To form an idea of the size of these 1918 estimates, attention is called to the costs of both branches of the military establishment of the United States for the War of 1812, the Second Seminole War, the Mexican War, the Civil War, and the Spanish War, all of which aggregated $3 743 776 773.

During the fourth to the fifteenth month, inclusive, of the present war it was projected to spend about two and one-half times the cost of all the wars of this country since it came into existence.

It is understood that during the first year of the war the total disbursements incident thereto aggregated a little less than $9 000 000 000, of which about $4 750 000 000 were loaned to the Allies. In other words, this country spent for all war purposes of its own during the first 12 months a little more than $4 000 000 000. What the figures will be at the end of the present fiscal year cannot now be told.

One of the reasons the United States was unable to carry out fully the programme first laid down was its inability to adjust itself to the exigencies of emergency construction work as speedily as was anticipated.

As a result of unpreparedness, an enormous burden was thrown suddenly on transportation and various other facilities, as well as on construction procedures of all kinds, particularly the markets for labor and materials. Steps toward co-ordination in plans for effective procedure, and in adjustments between activities essential and non-essential for war, encountered the inevitable inertia to be found in a prosperous nation which had enjoyed peace for many years and had anticipated no ending to its path of peace. In the light of present knowledge, it is unnecessary to elaborate details to show the importance of handling emergency work in an adequate way, with much of which work the engineer has been and will be intimately associated.

Some of the emergency war work has been along the lines with which the officers of the military establishment have been very familiar. In the Navy, for instance, a large portion of the work has been that for which technical officers have been making exhaustive studies during a term of years. Lack of appropriations alone explains the slowness with which such work was accomplished in the past.

Although this paper deals particularly with the housing of the new National Army, in relation to the work of the Cantonment Division, because the writer was familiar with the organization of that branch of emergency construction work, it is by no means to be inferred that its importance and style of accomplishment justify ignoring the performances of other branches of the service. Indeed, the work of the Cantonment Division is taken simply as a matter of convenience to illustrate certain principles stated at the end of this paper, which are believed to be of fundamental importance in the handling of emergency work under war conditions.

The Navy, since December, 1916, through its Bureau of Yards and Docks, has concluded 496 contracts, involving a total expenditure of more than $96 000 000, for developing existing yards and providing training camps for the increased personnel. The Bureau of Ordnance increased its yearly rate of expenditure from $30 000 000 to more than $560 000 000. The Bureau of Navigation put into commission during the past year more than 1 000 vessels, ranging from battleships and destroyers down to gunboats and yachts, and has worked out a programme for handling all these vessels as well as for training the men who will be required to man new vessels expected to be put into commission in the future. The Navy has re-acted well under the emergency conditions incident to the present war, and it is the belief of the writer that this is explained largely by the fact that the officers knew at the outbreak of the war what they wanted to do and how they wanted to do it. Then it became a question of funds to permit their programme to be executed with a minimum outlay of time and money.

In the War Department the situation was somewhat different, largely, of course, on account of the long-continued peace policy which the country had sanctioned, to the extent perhaps of discouraging Army officers from working out detailed plans under hypothetical conditions which could not be gauged accurately in advance by any one. It is not the intention of the writer to speak disparagingly of the War Department. On the contrary, it is believed that it has performed surprisingly well, on the whole, when consideration is given to its inactive antecedents, for which the citizens of the country were actually if not actively responsible.

Brief reference should be made to the Shipping Board. At the time of the recent Congressional investigation of the Board, Chairman Hurley reported that he had under construction 1 427 ships of 8 573 108 tons, dead weight. Of these, 431 were ships commandeered on the stocks from private owners, for whom they were being built at the time the Board took over the shipping business of the country.

Of the new ships contracted for by the Board through its Fleet Corporation, 559 are steel, 379 wood, and 58 composite.

The Board has had about $2 000 000 000 with which to work. A most important part of its labors, so far, has been devoted to the extension of advice and financial assistance to 42 different shipyards. Ships are building on the Board's own contracts in 110 yards, only 36 of which were in existence at the beginning of 1917. Requisitioned ships are building in 22 additional yards.

There have been many fields of activity of the War Department of which, obviously, no mention may be made in this paper. A glance at Table 1 suffices to indicate some of the developments other than as to the Engineer Corps and Quartermaster Corps. Thus, in the Ordnance Department, Maj.-Gen. William Crozier, M. Am. Soc. C. E., testified before a Congressional Committee at the end of 1917 that up to December 15th, 1917, the Department had entered into 718 contracts for artillery ammunition, aggregating $1 000 000 000 and averaging more than $1 125 000 each. Between the middle of May and the middle of December, 1917, the Department had placed contracts for more than 63 000 000 shells of a total value of more than $1 000 000 000. The industrial organizations of the United States, of course, had had an opportunity to prepare for war work, as their engineering and administrative staffs had obtained experience through the fulfillment of munition orders for nearly 3 years for European governments. Mention is made of this point partly to illustrate the scope of engineering service demanded by modern warfare and partly to emphasize the fact that lessons as to correct principles of engineering procedure in emergencies ought to apply generally to engineering work in its broadest phases, although detailed experiences must of necessity be limited to lines with which there is personal familiarity.

In reference to the work of the Cantonment Division, in housing the new National Army and the Federalized National Guard, the writer had the privilege of serving as a Central Sub-Committeeman under the Council of National Defense from May 19th to July 3d, 1917, during the second 6-week period of the war, and had an opportunity to come intimately in contact with the early organization and preliminary planning arrangements for this phase of the work which had to be done in such a hurry.

The second 6-week period of the war began when the Conscription Law was passed, and plans had to be formulated quickly, largely with the aid of civilians, pending the authorization by Congress of funds necessary to make workable an adequate official division for handling the housing of the National Army and Federalized National Guard.

This paper is devoted primarily to a description of the methods followed in getting this particular emergency work under way. Some statements are given as to what the new army camps really are, and finally, and perhaps most important of all, there are given some thoughts of the writer as to the principal lessons taught by the experiences of 1917 on emergency construction work due to war conditions. Essentially, in the view of the writer, the main lesson is that of adequate engineering direction. All other deductions and conclusions, applicable to the emergencies either arising from war conditions or due to any other of a series of emergency causes, are a part of or revolve about this question of adequate direction of engineering work.

CAMP CONSTRUCTION DURING THE FIRST SIX WEEKS OF WAR.

After the war in Europe had been raging for two and two-thirds years, the United States found itself a participant therein. The country had hoped to keep out of the world war, for which there had been very few preparations made, except those incidental to supplying certain war necessities to European countries.

It is the Quartermaster Corps and not the Engineer Corps that attends to construction work incident to Army posts. The Engineer Corps had its tasks in Europe. In the Quartermaster General's Office there was a Division of Construction and Repair, and at the outbreak of the war it was composed of three officers, Col. Littell, Capt. Oury and Capt. Marshall, with a force of 20 clerks and stenographers and about 20 engineers, architects, and draftsmen. At the Regular Army posts this force kept all structures in repair and made such extensions as were necessary from time to time to house the Army.

When the war broke out, it was this little Division that faced the task of housing the enormous increase in the personnel of the Army. How to proceed at once was a puzzle, as it was not known whether or not the Conscription Bill would become a law until definite action had been taken by Congress. Hence, until Congress passed that law, plans could really assume no formal shape.

All that could be done was to build additional barracks at the various Army posts, provide officers' training camps to supplement those already in existence, and provide certain aviation fields and the like. During the first 6 weeks of the war—April 6th to May 18th—about $6 000 000 worth of work was put under contract for additional housing facilities of the Army, and this was done through the Construction and Repair Division of the Quartermaster General's Office. Investigations of new camp sites were ordered on May 7th, 1917.

Increase in Personnel of Armed Forces.

To realize the magnitude of the problem in hand, it may be stated that at this period the programme was to provide housing for an increase of about 1 100 000 men to be added to the Army of the United States.

The published figures (Table 2) are interesting as they enable one to compare the actual increases.

TABLE 2.—Growth of Armed Forces of the United States, 1917-18.

		April, 1917.	March, 1918.
Regular Army		128 000	513 000
National Guard in Federal Service		80 446	450 000
National Army, Reserve Officers and Officers in training (by difference)		3 588	689 725
Total Army		212 034	1 652 725
Growth of Army during first year of war, without counting new draft men reporting on or about April 1st, 1918:			
Officers	114 277		212 034
Men	1 326 414		
			1 440 691
Navy		83 000	350 000 83 000
Growth of Navy			267 000
Growth of Army and Navy			1 707 691

Conscription Law of May 18th, 1917, and Steps Then Instituted.

On May 18th, 1917, Congress passed the Conscription Law, providing for the new National Army. This was the turning point in preparatory steps, and immediately there was instituted a definite programme along various lines. The Secretary of War was then in a position to act on numerous matters which had been under advisement by the General Staff, and by the Munitions Board of the Council of

National Defense, which already had formed a sub-committee on Emergency Construction of Buildings and Engineering Structures.

This committee recommended that Col. (afterward Brig.-Gen.) Littell, of the Quartermaster Corps, be designated as the Officer in Charge of Cantonment Construction. He was appointed and authority was granted to him to report directly to the Secretary of War, to communicate directly with department and division commanders, by order of the Secretary of War, and to direct travel of officers and civilians under him.

The General Staff determined that cantonments should be constructed in sixteen different places, situated in the several sections of the country so that each site would have tributary to it its *pro rata* share of the conscripted army. The Federalized National Guard camps were to be mostly in the South and West, where climatic conditions would permit training practically throughout the year.

Under the Committee on Emergency Construction there was a subcommittee to aid on preliminary planning, sanitation, and engineering relative to cantonment work.

Congress was debating an Army Deficiency Bill, in the sum of about $78 000 000, of which about $6 000 000 had been anticipated for training camps and new barracks at various army posts. This date—May 18th, 1917—marks the beginning of the second 6-week period of the participation of the United States in the World War, and the commencement on a large scale of various lines of emergency construction work, of which mention in the following pages will be confined essentially to that of the Cantonment Division.

CIVILIAN COMMITTEES.

Under the Council of National Defense, acting through the Munitions Board (afterward the War Industries Board), members of the Committee on Emergency Construction were appointed as follows: Chairman, William A. Starrett, M. Am. Soc. C. E., of New York; Frederick Law Olmstead, of Boston; M. C. Tuttle, of Boston; C. W. Lundorf, of Cleveland; and Maj. William Kelly, Assoc. M. Am. Soc. C. E., of the Engineer Corps, U. S. A.

Under this Committee on Emergency Construction there was a subcommittee on preliminary planning, sanitation, and engineering relative to cantonment work. This committee, reporting through Mr.

Olmstead of the Main Committee, was composed of Leonard Metcalf, George W. Fuller, and Asa E. Phillips, Members, Am. Soc. C. E.

Associated with this committee there were other civilian engineers, who joined the service later. They constituted a central office force of the Cantonment Division, in Washington.

Under the Munitions Board there were other committees on various construction supplies, labor, transportation, priorities, storage facilities, auditing, etc.

At this time, Gen. (then Col.) Littell, and Colonels (then Captains), W. H. Oury and R. C. Marshall, Jr., had neither funds nor personnel with which to proceed formally in this large undertaking of cantonment construction. With the exception of one chief clerk, the remainder of the Construction and Repair Division of the Quartermaster General's office was actively occupied with the enlargements at the several Regular Army posts.

At the suggestion of the Committee, the engineering work of the Cantonment Division was placed in the hands of F. M. Gunby, of the Engineering Staff of Charles T. Main, M. Am. Soc. C. E., Mechanical Engineer, of Boston, Mass., who was commissioned a Major in the Quartermaster Reserve Corps. His principal assistants were George Gibbs, Jr., from the staff of the City Planning Board, Boston, Mass., who was placed in charge of the drafting-room; and water supply and sewerage matters were placed in the immediate charge of Dabney H. Maury, M. Am. Soc. C. E., Consulting Engineer, of Chicago, Ill., who was aided by Clarence Goldsmith, M. Am. Soc. C. E., and Mr. W. N. Johnson, of the Engineering Staff of the National Board of Fire Underwriters, of New York City. Mr. Robert E. Hamilton, formerly purchasing agent of Stone and Webster, was commissioned a Major, and placed in charge of materials and transportation. He resigned later and was succeeded by Maj. (now Col.) J. M. Willcutt. Accounting was placed in charge of Maj. Dempsey, of the Quartermaster Reserve Corps, who was connected with the clerical work of the military establishment for many years. He was succeeded later by Maj. (now Lt.-Col.) Charles Nevill.

During the last week in May, the engineering organization was expanded rapidly to 10 engineers, 19 draftsmen, and 7 clerks and stenographers, making a total force of 36.

A statement as to the early personnel of this organization would not be complete did it not record the fact that Colonels Gunby and Willcutt had each served for about a dozen years in the National Guard, and that the experience thus acquired was of invaluable aid in allowing the Division to build the National Guard camps at the extraordinary rate of speed actually accomplished.

To take charge of the administrative work of construction from the central office in Washington, at the suggestion of the Committee, Mr. M. J. Whitson, of Seattle, Wash., now Colonel in the Quartermaster Corps, N. A., was appointed.

SELECTION OF CANTONMENT SITES.

The General Staff directed the Commanding General in each of the six Departments to select sites which would provide in the aggregate for 16 National Army Camps and 16 National Guard camps. The Commanding Generals who received preliminary orders on May 7th were instructed to report by the end of May. They selected from their forces committees of officers who inspected various sites brought to their attention. On these committees it is understood there was ordinarily one engineer officer, one medical officer, and one line officer. The reports of the inspections by these committees, with certain recommendations, were made to the Commanding General of the Department, who telegraphed his findings and transmitted his report to Washington for the consideration of the General Staff, who decided on the sites, subject to the approval of the Secretary of War.

Most of these cantonment sites were selected early in June, and the last was approved on June 27th.*

PRELIMINARY ESTIMATES OF COST OF CAMPS.

One of the first things to which the Committee on Emergency Construction and its technical associates gave attention was the estimate of cost of housing the new Army, and the appropriation therefor then pending before Congress.

Table 3 shows, in the left-hand column of figures, the first provisional estimate, prepared on March 13th, 1917, and based in large

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* Lantern slides were shown indicating the location and arrangement of the Army camps, with plans, sections, and other details of representative structures. As such technical details have been already published in the engineering press, and as this address deals particularly with matters of organization and management, they are not here reproduced.

TABLE 3.—Comparison of Early Estimates of Cost per Man of New Army Camps.

Date	March 13th, 1917.	May 26th, 1917.
Total men	1 051 270	1 103 496
Total estimate	$78 365 798.75	$192 393 200
Barracks and Quarters:	*Per Man.*	*Per Man.*
Construction	$42.00	$61.98
Wall boarding	......	3.47
Screening and screen doors	......	2.51
Rental of camp site	2.00	0.31
recreation stations	1.184	......
lodgings	0.92	......
Allowance for contingencies, 10%	......	6.83
Supplies, Services, and Transportation:		
Plumbing	......	7.75
Heating, stoves	......	9.31
steam	......	......
Power plant	......	3.10
Electric lighting, interior	......	2.79
exterior (camp limits)	......	0.68
Water system	1.75	6.26
Sewer system		2.32
Maintenance, water and sewer systems	0.175	......
Sewage disposal	......	6.21
Laundry	......	6.33
Fire apparatus, including buildings	......	1.89
Garbage incinerator plant	......	0.77
Ice and refrigerating plant	......	3.87
Bunks	......	4.18
Mattresses	......	5.43
Ranges	......	0.62
Refrigerators	......	0.62
Allowance for contingencies, 10%	......	6.17
Toilet paper	2.00	......
Garbage disposal	3.00	......
Purchasing water	4.80	......
Electric current	4.80	......
Roads, Walks, Wharves, and Drainage:		
Roads	5.00	5.43
Drainage		0.93
Clearing		0.62
Railroads	......	2.33
Maintenance, roads	0.50	......
Allowance for contingencies, 10%	......	0.93
Construction and Repair of Hospitals:	2.10	18.92*
Shooting Galleries and Ranges:	2.00	2.26
Total estimates	$72.229	$174.35
Actual Costs Reported to Congress:		
National Army Cantonments	......	$214.92
National Guard Camps	......	87.60
Average of cantonments and camps	......	151.26

* Estimate of Medical Department of Army.

measure on experiences in housing the National Guard while in service on the Mexican border during 1916. It is interesting to note that the early estimates provided for no sewer system at all, and for water supply only in so far as piping was necessary to distribute water among the buildings. In several particulars they refer to service and maintenance charges, and not to construction work. The estimates for barracks and quarters provide, for the most part, for housing the men under canvas, as was done at the Mexican border. Little or no recognition was given to the fact that in 1916 the Guardsmen themselves did much of the work that was done as to flooring tents, digging latrines, etc. Furthermore, no adequate account had been taken of the marked increase during the intervening year in the prices of labor and materials, particularly such as would appear when an enormous quantity of construction work would be called for in an incredibly short period of time at any given locality.

It is not surprising, therefore, that, at the end of the first week's deliberation, the preliminary estimates, with their allowances for modern sanitary conveniences in the interests of the health of the Army, were markedly higher than the figures which had previously been sent to Congress. Note the right-hand column of figures in Table 3.

During the last week in May there was uncertainty as to how many of the new army should be placed in wooden barracks and how many under canvas. The Secretary of War decided, before the end of May, to establish cantonments with wooden barracks at sixteen of the sites to be used for the new National Army, with water supply and sewerage arrangements to meet fully all reasonable demands. The sixteen National Guard camps were arranged for the troops to be quartered under canvas, with wooden shacks for the kitchens and mess-halls. A water supply somewhat more limited in quantity than at the cantonments was to be provided. Latrines, however, were prescribed for the National Guard camps, and not sewerage arrangements, on account presumably of the more temporary nature of the Guard camps as compared with the cantonments.

It was proposed to call the conscripted men to camp during the first week in September and hence, when the programme had become formulated to the stage above indicated, there remained only about 90 days in which to complete the plans in Washington for general arrangements, prepare specifications and contracts, select the contractors, organize field forces for the Contractor, Quartermaster Corps, Supervising Engineer, and Auditing Division, as well as to build at each of the sixteen sites a cantonment estimated to cost roughly $6 000 000, to house about 40 000 people and about 10 000 animals.

It is to be recalled that funds had not yet been appropriated by Congress, and that Col. Littell, the head of the Cantonment Division, was relying on civilian aid in a large measure, because lack of funds did not permit of a formal organization, even at Headquarters, of a staff commensurate with the work in hand. In fact, complete organization of the Cantonment Division was not feasible until after the Appropriation Bill became a law on June 15th.

Uncertain Features of Plans.—It is to be pointed out that at this stage there was little or no knowledge of the sites on which cantonments were to be built, or of their distance from transportation lines. It was not known what the official decision would be in regard to the ultimate standard company unit, which in the United States Army was then materially different from the company units in vogue among our allies in Europe. Multiples of the standard company units to form battalions, regiments, brigades, and divisions, were all subject to this uncertainty, awaiting recommendation to the General Staff from Gen. Pershing, who reached Europe on June 15th, and who, obviously, was obliged to consult and investigate before reaching his own conclusions in reference thereto.

At this juncture it was necessary to recognize in a very clear way the urgency of getting typical plans advanced to a point where construction work could be actually begun at the earliest possible day, and to do it in such a way that flexibility of procedure would permit the later adjustment to the standard army units to be recommended by Gen. Pershing, and to make such sanitary provisions as would give to the American people a feeling that their sons in the National Army would receive a square deal, from a health standpoint.

Under these circumstances there was ample opportunity for this mixed personnel of army officers and civilians to precipitate themselves into the pitfall of debate and indecision. There was a natural desire for the proponents of these construction projects to do their work well; but, to falter over the idealization of plans which could not possibly be put on a final basis at this time was a mishap that the Cantonment Division, during the days of its early organization, must receive credit for avoiding to a substantial extent. The men dealing with the enterprise did get it quickly on a workable basis, which saved precious time in getting our new Army in camp, and likewise permitted an adjustment of the construction programme to decisions which did not take definite form in some instances until the camps were practically half built.

Unquestionably, this added somewhat to the cost, but the writer is firmly of the opinion that it was a sound step, because time was more valuable than the money invested for emergency work of this character; and, in general, it is a good rule on emergency construction work to proceed at once with that which is moderately satisfactory and then make betterments later, when circumstances permit or justify.

Typical Plans.—Plans were prepared for a two-story barrack building, about 43 by 140 ft., designed for 150 men, and providing about 365 cu. ft. of air space per man. Later, some of these buildings were increased in length to accommodate 200 men. The final plan adopted was a building, 30 by 60 ft., to house 66 men, so that, for the new standard company unit of 250 men, there would be four of these barracks for a company, in addition to a mess hall and lavatory Officers' quarters are about 20 by 100 ft., with individual rooms 8 by 10 ft. Later plans showed 500 cu. ft. of air space per man.

The grouping of about 1 700 buildings into a general layout obviously depended on the locality, about which little or nothing was known in Washington at this time. It could not be ascertained whether the sites were on a fairly level plain, or on a single ridge, or on broken ground. The grouping of the company buildings, with officers' quarters, regimental quarters, headquarters department, and various other buildings at a cantonment, were arranged on typical layout plans of two types. These are known as straight-line and U-shape layouts. It was recognized as highly improbable that either typical plan could be followed strictly, and it was known that variations in topography would require adjustments on the ground.

This called at once for steps to ascertain the local conditions at the several selected camp sites, and to have this information in hand at the earliest practicable date. Rough topography, as to Camp Devens, Ayer, Mass., necessitated much re-arrangement of the typical plans sent out from Washington.

It is unnecessary here to detail how these plans had to be modified on account of changes in standard army units, or in cubage of air space per man, or in added facilities for hospitals, remount stations, trains, and structures of various sorts. All these matters made much hard work for those in charge of the actual construction on the ground, and emphasized the importance of elasticity of procedure. Comments already made as to uncertainty in plans and as to fundamentally correct decisions regarding policy will be better understood as consideration is given to the individuality of the local sites, and the changes necessitated for a variety of reasons.

Probably it is unnecessary to remind the reader that, though this enterprise is made up of the construction of fairly simple units, as far as the structures themselves are concerned, yet, in justice to those having to do with the enterprise, it is well to bear in mind the magnitude of the undertaking, namely, the effort to build considerably more than $100 000 000 worth of structures in a period that should be just as close to 90 days as possible, and in fact in less than 90 days, to make it feasible to receive at camp the first quota of the conscripted army during the first week in September.

Plans for camps for the Federalized National Guard were considered at Washington after those for the cantonments, notwithstanding that the Guard was called to service earlier than the conscripted army. Although costing about $38 000 000, little is said here of the Guard camps, because they offer no new phases of construction work as compared with the cantonments.

Preliminary Engineering at Sites.—As soon as sites for the cantonments were approved by the Secretary of War, it was necessary to aid the central office at Washington with data on several vitally important matters, depending on local conditions, as follows:

(*A*).—Transportation facilities and betterments needed for delivery of materials for rapid construction;

(*B*).—Topography, and adequacy of area to allow the needed structures of the cantonment to be grouped conveniently, so as to form a well co-ordinated camp plan; together with conditions as to soil, drainage, occurrence of mosquitoes, etc.;

(*C*).—Most suitable source of safe and ample water supply;

(*D*).—Arrangements as to sewerage, including general plan for disposal of sewage without nuisance.

At this time, there were no men to spare from the Engineer Corps or the Quartermaster Corps. Advantage had to be taken of the offers of civilian engineers throughout the country, who volunteered their services in aid of the Government, when no funds were available for making definite arrangements in pursuance of official authorization.

The Engineering Profession responded in a most gratifying manner to the urgent request of those dealing with this matter at Washington. In general, it was the purpose to have at least two civilians investigate conditions at each cantonment site, one of these men to be a town planner, and the other an engineering expert in matters of water supply and sewerage. In several instances, more than two men were placed on the local board for preliminary engineering, and advantage was taken wherever practicable of the special knowledge of engineers familiar with local sanitary conditions in the general vicinity of the cantonment.

The local engineering boards performed their work quickly and creditably, and in many instances brought their data to Washington in person to explain the main features to those in charge of the engineering work in the Cantonment Division.

Table 4 contains the names of the civilian engineers and town planners aiding on these preliminary reports.

TABLE 4.—CIVILIAN ENGINEERS AND TOWN PLANNERS ON PRELIMINARY REPORTS.

Camps.	Civil Engineers.	Town Planners.
Devens	Frank A. Barbour, M. Am. Soc. C. E.	H. J. Kellaway
Upton	Walter E. Spear, M Am. Soc. C. E.	F. Vitale
Dix	Allen Hazen, M. Am. Soc. C E. John D. Kilpatrick	Charles D. Leavitt, Jr.
Meade	Morris Knowles, M. Am. Soc. C. E.	Owen Brainard, M. Am. Soc. C. E.
Lee	H. R. Messer, Assoc. M. Am. Soc. C. E. Allen J. Saville, Assoc. M. Am. Soc. C. E.	James L. Greenleaf
Jackson	P. H. Norcross, M. Am. Soc. C. E.	Richard Schermerhorn, Jr., M. Am. Soc. C. E.
Gordon	James N. Hazlehurst, M. Am. Soc. C. E. G. R. Solomon, M. Am. Soc. C. E.	A. F. Brinckerhoff Charles N. Lowrie
Pike	E. B. Black, M. Am. Soc. C. E.	George E. Kessler L. V. Sheridan, Assoc. M. Am. Soc. C. E.
Sherman	R. Winthrop Pratt, M. Am Soc. C. E. William H. Dittoe, Assoc. M. Am. Soc. C. E. J. W. Ellms, M. Am. Soc. C. E. Clarence Hoover	Warren H. Manning and Son
Taylor	James B. Wilson, Assoc. M. Am. Soc. C. E.	Harlan P. Kelsey
Custer	Samuel A. Greeley, Assoc. M. Am. Soc. C. E.	Thomas W. Sears
Grant	John W. Alvord, M. Am. Soc. C. E.	E. H. Bennett
Dodge	Louis P. Wolff, M. Am. Soc. C. E.	Robert Wheelwright
Funston	Wynkoop Kiersted, M. Am. Soc. C. E.	J. S. Pray S. Herbert Hare
Travis	Robert J. Harding, M. Am. Soc. C. E.	George E. Kessler
Lewis	William J. Roberts, M. Am. Soc. C. E. R. H. Thomson, M. Am. Soc. C. E.	E. N. Noyes, M. Am. Soc. C. E. C. F. Pilat

SUBJECTS CONSIDERED BY COMMITTEE ON EMERGENCY CONSTRUCTION.

While this committee, and the sub-committee working under it, were devoting themselves to questions of personnel for the central office of the Cantonment Division, and for local preliminary engineering investigations, there were numerous conferences on typical plans for the cantonment work, and discussion relative to forms of contract, the selection of contractors, and field organizations to represent the Cantonment Division in its direction of construction work.

By no means should a statement on engineering work omit reference to the important efforts of associated committees on canvassing the availability of construction materials, transportation facilities, and on making arrangements to facilitate the auditing and checking of accounts in order to allow the Government to make reasonably prompt payments to the contractors.

To show what was dealt with at the meetings, held each morning at 8 A. M., by the Committee on Emergency Construction, and associated sub-committees, it is of interest to record the topics considered early in June, as follows:

Selection of Site; Acceptance of Site; Topography of Site; Investigation and Decision, Water Supply; Investigation and Decision, Sewerage; Selection of Engineers, and Contracts with Engineering Firms; Selection of Contractors; Final Decision and Acceptance of Building Design; Adaptation of Building to Site; Basis of Sub-Contracts; Percentage of Profit Paid to Contractor; Shall Contractor or Government pay Sub-Contractor's Profit?; Approval of Sub-Contractor; Contractor's Time Schedule; Assembling Sources of Men; Assembling Sources of Supplies; Bills of Material; Placing of Orders; Inspection of Materials; Schedule of Delivery of Materials; Organization of Contractor's Forces; Camp Sanitation During Construction; Quarters for Workmen; Provision for Storage Facilities; Subdivision of Monthly Requisitions; Definite Decisions on Method of Accounting; Installation of Checking Force; If Government Holds up Payment, can Contractor do Likewise to Sub-Contractors and Material Men?; Will Interest be Paid to Contractors on all Payments Held up?

Selection of Contractors.—While preliminary data were being procured at the camp sites, and while Congress was still considering the Appropriation Bill, the Emergency Construction Committee proceeded to secure data concerning contracting firms believed to be capable of coping with the magnitude and kind of work here involved, and who had at hand organizations and financial resources adequate to permit of their executing the construction work of a cantonment at the phenomenally high rate of speed necessitated by existing circumstances.

Questionnaires were sent to various contracting firms who had handled work of magnitude during the two preceding years. Great assistance was derived from Mr. John H. McGibbon, formerly of the United States Fidelity and Guarantee Company, of Chicago, who brought to the aid of the Committee his broad knowledge of the standing and financial credit of various leading contractors.

Contractors were selected by a special committee of five men under the chairmanship of Major W. A. Starrett, of the Committee on Emergency Construction. These selections were made on the basis of the past experiences of the contracting firms for handling work on a large scale, and the findings were reported to the Munitions Board. The recommendations were then sent to Gen. Littell, who placed the evidence before the Secretary of War for approval. This procedure has been consistently followed since that time.

Taking everything into account, it is believed that these contractors were selected wisely, and that they compare very favorably with those who do work on a large scale for municipalities and leading private corporations in this country. Certainly, political influence cut very little figure in their selection. It is also to be said, to the credit of the contractors, that there were a number who were willing to undertake this work for the customary $1 plus expenses.

If criticism were to be made as to the selection of the contractors, in the light of present knowledge, it would probably be directed toward the scant appreciation given to the important element of past experience with rough work in open country where an organization had quickly to provide housing and rationing arrangements for many thousands of men in practically rural communities. Difficulties of this sort and with the labor conditions made the work at some camp sites proceed with disappointing speed at the outset, even to the extent of requiring practically a reorganization of the contractors' forces.

The contractors, on the whole, however, made a most creditable record, and it is not likely that substantial improvement could be expected on the records of the entire work under the Cantonment Division.

Form of Contract.—Bearing in mind the urgency of getting the cantonments under construction at the earliest possible day, with registration of the young men of the country within draft age having already occurred on June 5th, with the understanding that the first quota of the drafted men were to report at camp on September 5th, with only meager data about a few of the camp sites actually selected, and with the uncertainty as to the changes which would have to be made in typical plans, it is not surprising that the civilians in Washington contended strongly for the abandonment of the ordinary form of Government contract.

Indeed, new barracks at army posts, officers' training camps, aviation fields, and the like, during the first 6 weeks of the war, had been built without competitive bidding. It was generally realized at that time that the market for labor and materials was extraordinarily unstable, and likely to become more so in certain centers of construction activity. Competitive bidding was entirely out of the question, either on a lump-sum or unit-bid-price basis. It would not have been fair, either to the Government or to any contractor.

Valuable time had to be saved, and a flexibility of programme between the Government and the contractor, as regards inevitable changes, had to be provided.

It was determined to adopt the form of contract which has been much discussed during the past year, both in Congress and in the technical papers. It is known as the "cost-plus-a-sliding-scale-fee" form of contract, with maximum upset fee.

This form of contract is now in its third edition, the second having appeared in October, 1917, and the third in February, 1918. Changes in its successive editions have not been material, except as regards the adjustment of the maximum fee in its relation to the ranges in maximum estimated costs.

Article III of the contract provides that if the cost of the work is \$100 000 or less, the contracting officer shall pay to the contractor 7% of such cost; if the cost is \$100 000 and less than \$125 000, a fee of \$7 000; and if the cost is more than \$125 000 and less than \$450 000, a fee of 6½%; if the cost is more than \$450 000 and less than \$500 000, a fee of \$29 250; if the cost is more than \$500 000 and less than \$1 000 000, a fee of 6 per cent.

The percentage fees, with intermediate lump-sum fees for intermediate ranges similar to the foregoing, may be briefly noted for increasing costs as follows:

- 5½% for work costing more than $1 100 000 and less than $1 500 000;
- 5% for work from $1 650 000 to $2 200 000;
- 4½% for work from $2 450 000 to $2 850 000;
- 4% for work from $3 250 000 to $4 000 000; and so forth.

The fees progressively decrease as the cost of the work increases, until a fee of 2½% applies to a cost of more than $9 650 000 and less than $10 000 000. A maximum upset fee of $250 000 applies when the cost of the work is more than $10 000 000.

This style of contract was approved by the Emergency Construction Committee for the cantonment construction work.

The union scale of wages prevailing in the locality of the work under consideration as of June 1st, 1917, was agreed upon by the Secretary of War and the President of the American Federation of Labor as the scale for the camp. Rules in reference to over-time, and for the regulation of hours of work, were agreed upon in advance between the constructing quartermaster and the contractor, in accordance with conditions prevailing in the district where the work was done.

The wage scale is by no means the only puzzling phase of the cost of emergency construction work to be carried out at a phenomenally high rate of speed. The efficiency of labor is a factor of serious moment, as is also the adjustment of the quantity of labor to the quantity of work to be done with construction materials actually at hand, and subject to delays in transportation to a varying extent day by day.

Without doubt, there was some lost motion in the way labor was handled at some of the cantonments. This was probably true to a greater extent at the beginning of construction than it was after the contractors got their expanded organizations well in hand. Efficiency, as ordinarily noted, was not to be expected under these circumstances, as time was of more importance than the close fitting of the pay-roll to the handling of construction material coming to the job irregularly as a result of various factors.

It is stated by some that the later pay-rolls were more efficiently handled, after contractors were assured of their maximum fee of $250 000, than was the case at the outset. There may be something in this comment, in some instances, but, as a general proposition, it is the view of the writer that much of this apparent lost motion was explained by the inevitable period of time required by the contractor at the outset to stabilize his organization, so that he could pick up speed and efficiency in a more or less normal way. It is also to be borne in mind that on construction jobs, where 10 000 to 12 000 men or more were employed in districts where labor was already scarce, there was not a tremendously great opportunity to do too much choosing of labor. The contractors, in fact, during most of the time, took what labor they could get, and all they could get.

The question of whether or not the Government got a fair return in its investment depends in part on the adequacy of the auditing and checking system which the Constructing Quartermaster instituted on the job. Still another phase of the situation is that of the slow pay, for which the Government had quite a reputation prior to the war. There is little doubt about there being some instances where contractors held thousands of men on their pay-rolls for some days, because they did not have funds with which to pay the men. In the meantime the representatives of the Government were using their very best efforts to end the delays caused by the red tape so characteristic of construction work for the United States in earlier days.

Some contractors appeared in Washington with the viewpoint that they would prefer to supervise the construction work at any cantonment for $1 plus actual cost, rather than subject themselves to losses in interest on deferred payments by the Government. The writer brought up this viewpoint several times for active discussion, but, to break away from the long precedent of the Government not to allow interest on belated payments, was not looked on with favor.

It is necessary here to point out that net profits to the contractors were substantially less than indicated in the foregoing schedules of fees. Overhead expenses and interest costs are understood to have made the actual profit to the cantonment contractors substantially less than 2%, and less than 1½% in some cases.

On emergency work, where speed was vitally important, it has been and is the conclusion of the writer that the form of contract adopted was a wise one.

In this general connection, mention may be made of the effort of the Navy, on some of its recent contracts, to adopt a modification whereby, if there is a saving over the estimated cost, the contractor shall share it with the Government. This should serve as an incentive to economy for some classes and conditions of work.

Endorsement of Form of Contract by Special Committee.—The adopted form of contract brought forth criticism, as was naturally to be expected. It was intimated that the Government was not protected sufficiently against profiteering, particularly on the smaller jobs. Hence the War Department, early in 1918, called for a review of this emergency form of contract by a special Committee of Engineers, Architects, Business men, and Contractors, consisting of the following:

Professor A. N. Talbot, President, American Society of Civil Engineers, Urbana, Ill., Chairman;
John Lawrence Mauran, President, American Institute of Architects, St. Louis, Mo., Secretary;
John R. Alpine, representing the American Federation of Labor;
Frederick L. Cranford, President, General Contractors' Association of New York, Brooklyn, N. Y.;
Charles T. Main, President, American Society of Mechanical Engineers, Boston, Mass.;
Oscar A. Reum, representative of the President of the Building Construction Employers' Association, Chicago, Ill.;
R. G. Rhett, President, Chamber of Commerce of the United States, Charleston, S. C.;
E. W. Rice, President, American Institute of Electrical Engineers, Schenectady, N. Y.

This Committee was furnished by the Cantonment Division with complete data surrounding the emergency work with which it had been dealing, and outlined that which, on a still greater scale, it had yet to face.

The Committee unqualifiedly endorsed the form of contract. It pointed out that the "purchase and hire" method would have called for an impracticable amount of work from a central administrative office dealing with jobs in widely scattered locations. It declared that the resulting waste of valuable time by such a substitute method would be an insuperable objection. Besides, there is great desirability in maintaining the contractors' organizations in shape for effective work when the war is over. Competitive bidding, furthermore, on work calling for numerous changes, and with an unstable market for labor and materials, would force the contractors in self-protection to bid speculative prices, which would be disadvantageous to the Government.

The conclusions of this Committee on the emergency form of contract in its more important phases are well worth recording, as follows:

"Having advised, therefore, that these various forms be not used, and for the reasons stated, the committee unanimously concurs in advocating what may be termed the cost plus a sliding scale fee scheme of contract for both general contracts and sub-contracts. In this application it enjoys the same confidence in the building world as to the equities as does the lump sum contract, as is evidenced by its very extensive use. Its essential features are its applicability to projects great and small—its extreme flexibility with automatic adjustment of all variations in plan and scope. Under its terms the rates of pay for labor are known to be more equitable than under other methods. It requires for its successful application a painstaking review of the records and standing of contractors, just as is now made under existing methods to insure the selection of an organization which measures up to the requirements of the contemplated project, but without working any hardship, since no one can escape the axiom that in the final analysis each job can go only to one contractor.

"The committee believes that one of the objections charged to this form of contract is that it encourages extravagance and holds open temptations to increased cost because such increase is accompanied by increased compensation. The general form of contract now in use by the Cantonment Division in which the percentage decreases as the cost increases and is broken by fixed fees at intervals seems calculated to check effectually, if not prevent, this tendency. Moreover, under the contract proposed, the Government retains the right to control the prices of most materials and labor. Under these circumstances, it does not seem to the committee that such an objection would have any force in relation to this form of contract. No reasonable objection can be pointed out by any one possessing a full understanding of its equitable operation in practice, and, finally, this scheme appeals to the committee as possessing one qualification which must commend it to all thinking men—it permits starting actual work weeks and even months before the details are completely worked out and delineated, and permits the Government to push the job at any speed it may elect, changing at will its plan and scope but paying only what the work actually costs, plus a fee which is so reasonable as to be above the reach of fair minded criticism."

CONSTRUCTION QUARTERMASTERS AND THEIR INSTRUCTIONS.

On June 15th, the appropriation bill was signed by the President. On the same date, several contracts for cantonment construction were executed, and the last of these contracts was signed by June 27th. The latter date was necessitated by delays in securing approval of the last of the cantonment sites. As soon as the appropriation was available, the staff of Gen. Littell, of the Cantonment Division, was promptly expanded in the Washington office, and at the different cantonment sites. It is to be remembered that, until funds were available, the organization had been tentative and informal, made up in part of civilians who, as soon as their records could be completed and their tasks in hand finished, were to return to their civilian duties, and in part of civilian engineers who were to join the service in the Quartermaster Corps.

A Constructing Quartermaster was selected promptly for each cantonment. He was the official representative of the Government, who acted as disbursing officer and general manager of operations, and to whom contractors, engineers, accountants, and others went for their instructions. From the Washington office there was sent, under date of June 18th, a 27-page mimeographed set of instructions to the constructing quartermasters. These pages, of legal size, contained a concise description of procedure for the men who were to take local charge of cantonment construction for the Government, and included terse specifications for water supply, sewerage, sewage disposal, fire protection, etc., as will be mentioned in the following pages. The instructions also dealt with other matters requiring careful consideration, such as heating, lighting, kitchen ranges, refrigeration, laundries, etc. They stated the relations between the Government and the contractor, and steps to be taken by representatives of each in getting the materials and labor quickly in hand, and taking care of them during construction, with directions as to fire protection, guarding of property, and the like. A few of the general instructions in these orders are worthy of record as follows:

Carry to completion the buildings designated as barracks. which include kitchen and mess facilities, lavatories, officers' quarters, and storehouses.

Simultaneously with the above construction, carry to completion the water system, and, where designated, the sewer system.

All buildings not included in the section above will not be commenced until the barracks and mess facilities are completed, or until further orders relating thereto have issued from this office.

Such roads and railroad sidings as are absolutely necessary to carry out the building programme as above will be undertaken at once, their extent and cost to be reported to this office at the earliest possible date.

The Constructing Quartermaster will carefully examine the orders for material submitted by the contractor, and will see that the rates of delivery specified are not in excess of the capacity of the contractor to unload and utilize in the work.

The Chief of Staff directs that the artillery barracks, stables, and miscellaneous buildings pertaining thereto, be not undertaken until the last item of construction, or until further orders issue from this office, as it is possible that a change in programme relating to the artillery may be put into effect. It is believed that space should be left for them, as this will form a fire-break in case the artillery is removed.

Personnel.—There will be assigned to duty, with each Constructing Quartermaster, one consulting engineer and one expert water and sewer engineer, if found necessary. The Constructing Quartermaster will use these as a nucleus of his engineer force, and utilize to the fullest extent the engineering force of the contractor. Should the engineering force of the contractor prove inadequate, he will add assistance to his own force as needed.

There will likewise be assigned to duty, under the Constructing Quartermaster, one auditor or chief accountant for each cantonment The chief accountant will be responsible under the Constructing Quartermaster's orders for the necessary accounting staff, and will call on the Constructing Quartermaster for the necessary assistants. The Constructing Quartermaster is to report his needs to this office.

Material and Equipment.—When the construction contract is signed, this office will furnish the Constructing Quartermaster concerned a statement showing the materials located by the Government, and the dealers from whom these materials should be purchased by the contractor. This statement will show the quantity of material each dealer can furnish, the price, and the rate of delivery.

It will be necessary for the contractor in most instances to furnish small tools and machinery equipment required for the work. The conditions under which these purchases are to be made are defined in the contract.

It is not probable that the materials located by the Government will cover all the requirements necessary for complete construction of the cantonment. The Constructing Quartermaster and the contractor will go over the list of requirements and approval should be given for the purchase by the contractor of all material, small tools, and equipment not provided by the Government, and for such material as may be necessary and available in the local markets for the conduct of the contractor's early operation prior to the arrival of material ordered on regular schedule in connection with cantonment construction. It will be necessary at all times that the contractor be given every assistance calculated to expedite his work and to relieve him from hampering restrictions of any sort.

Transportation.—The contractor will furnish certificates to the Constructing Quartermaster showing:

1.—Kind of material,
2.—Approximate number and classes of cars required,
3.—Approximate dates on which cars are required,
4.—Point of shipment,
5.—Destination.

The Constructing Quartermaster will forward two copies of each statement to the Washington office. One of these copies will be filed with the Commission on Car Service of the American Railway Association, for its advance information as to car requirements.

Sub-Contracts.—The terms and conditions under which sub-contracts can be entered upon are fixed by the general contract.

Sub-contracts are not looked upon with favor, and should in every case have the approval of the Contracting Officer. Questions of doubtful interpretation should, wherever possible, be referred to the Construction Officer for his approval.

Guard Duty.—As soon as the cantonment site is selected, and the Constructing Quartermaster is assigned, a military unit will be sent to the site to guard the camp. The guard will be disposed by the officer in command, in accordance with the necessities, as indicated by the Constructing Quartermaster. In cases where circumstances prevent the assignment of a military unit for police duty, this matter will be arranged as directed by the Construction Officer.

Hospital and Medical Services.—The contractor must provide his own hospital and medical services. When a military unit is assigned to a cantonment for guard duty, medical and hospital services will be provided for the guard.

Contractor's Quarters.—During the construction of the cantonment buildings, the Constructing Quartermaster at each place is instructed to permit the contractor to house his men in the barracks as constructed for one regiment except, of course, such men as the Constructing Quartermaster might deem to be unfit to be so housed, such to be placed in buildings built especially for them.

The Constructing Quartermaster is further instructed, upon the contractor's men vacating buildings they have occupied, to have the buildings thoroughly cleansed and fumigated by the contractor, under the direction of a Medical Officer of the Army.

Fire Protection.—The contractor should provide fire protection for material stored on the cantonment site and for completed work during the period of construction. Prior to the development of the general water supply for the cantonment, the Constructing Quartermaster and the contractor should decide on the most feasible method of protection with the means at hand, which should be put into effect promptly, and continued until no further use for it exists.

Supplies.—The Constructing Quartermaster will secure the necessary supplies for carrying on the work as necessity arises.

Constructing Quartermasters have been selected for this work who have had extensive experience in commercial and other building, and are eminently capable of handling jobs of this sort. There is assigned to each cantonment an officer of the Regular Army, and he, or an assistant, will be in charge. This assignment has been made with a view to utilizing his services in looking after the military and administrative end of this construction. Hearty co-operation therefore, should exist between the Constructing Quartermaster and all his assistants.

PERSONNEL OF CONTRACTORS AND CONSTRUCTING QUARTERMASTERS.

The Contractors who built the several army camps, and the Constructing Quartermasters in charge of the work in behalf of the Government, were as follows:

National Army Cantonments.

Seventy-sixth Division.—Camp Devens, Ayer, Mass. Contractor, Fred T. Ley and Company, Springfield, Mass. Constructing Quartermaster, Capt. Edward Canfield, Jr.

Seventy-seventh Division.—Camp Upton, Yaphank, N. Y. Contractor, Thompson Starrett Company, New York City. Constructing Quartermaster, Maj. O'Kelly Myers.

Seventy-eighth Division.—Camp Dix, Wrightstown, N. J. Contractor, Messrs. Irwin and Leighton, Philadelphia, Pa. Constructing Quartermaster, Maj. Harry O. Williams.

Seventy-ninth Division.—Camp Meade, Annapolis Junction, Md. Contractor, Smith, Hauser and MacIsaac, New York City. Constructing Quartermaster, Maj. Ralph F. Proctor, M. Am. Soc. C. E.

Eightieth Division.—Camp Lee, Petersburg, Va. Contractor, Rhinehardt and Dennis, Charlottesville, Va. Constructing Quartermasters, Maj. F. B. Edwards, Maj. E. K. Coe, M. Am. Soc. C. E., and Maj. E. H. Abardie.

Eighty-first Division.—Camp Jackson, Columbia, S. C. Contractor, Hardaway Constructing Company, Columbus, Ga. Constructing Quartermaster, Maj. William Couper.

Eighty-second Division.—Camp Gordon, Atlanta, Ga. Contractor, Arthur Tufts Company, Atlanta, Ga. Constructing Quartermaster, Maj. James N. Pease.

Eighty-third Division.—Camp Sherman, Chillicothe, Ohio. Contractor, The A. Bentley Company, Toledo, Ohio. Constructing Quartermaster, Capt. Ward Dabney.

Eighty-fourth Division.—Camp Taylor, Louisville, Ky. Contractor, Mason and Hanger, Richmond, Ky. Constructing Quartermaster, Maj. F. E. Lamphere, M. Am. Soc. C. E.

Eighty-fifth Division.—Camp Custer, Battle Creek, Mich. Contractor, Porter Brothers, Detroit, Mich. Constructing Quartermaster, Maj. Earle B. Morden.

Eighty-sixth Division.—Camp Grant, Rockford, Ill. Contractor, Bates Rogers Construction Company, Chicago, Ill. Constructing Quartermaster, Maj. D. H. Sawyer.

Eighty-seventh Division.—Camp Pike, Little Rock, Ark. Contractor, James Stewart and Company, New York City. Constructing Quartermaster, Maj. John R. Fordyce.

Eighty-eighth Division.—Camp Dodge, Des Moines, Iowa. Contractor, Charles Weitz and Sons, Des Moines, Iowa. Constructing Quartermaster, Col. M. A. Butler, Assoc. M. Am. Soc. C. E.

Eighty-ninth Division.—Camp Funston, Fort Riley, Kans. Contractor, George A. Fuller Company, New York City. Constructing Quartermaster, Capt. F. J. Herman.

Ninetieth Division.—Camp Travis, Fort Sam Houston, San Antonio, Tex. Contractor, Stone and Webster Corporation, Boston, Mass. Constructing Quartermaster, Lt.-Col. G. E. Thorne.

Ninety-first Division.—Camp Lewis, American Lake, Wash. Contractor, Hurley Mason Company, Tacoma, Wash. Constructing Quartermaster, Maj. D. L. Stone.

National Guard Mobilization Camps.

Twenty-sixth Division.—Camp Greene, Charlotte, N. C. Contractor, Consolidated Engineering Company, Baltimore, Md. Constructing Quartermaster, Maj. C. H. Greene.

Twenty-seventh Division.—Camp Wadsworth, Spartanburg, S. C. Contractor, Fiske-Carter Construction Company, Greenville, S. C. Constructing Quartermaster, Lt.-Col. J. D. Kilpatrick.

Twenty-eighth Division.—Camp Hancock, Augusta, Ga. Contractor, T. O. Brown Company, Augusta, Ga. Constructing Quartermaster, Maj. Gratz B. Strickler, M. Am. Soc. C. E.

Twenty-ninth Division.—Camp McClellan, Anniston, Ala. Contractor, John O. Chisolm and Company, New Orleans, La. Constructing Quartermaster, Col. L. C. Dulin.

Thirtieth Division.—Camp Sevier, Greenville, S. C. Contractor, Gallivan Building Company, Greenville, S. C. Constructing Quartermaster, Maj. A. G. Doyle.

Thirty-first Division. Camp Wheeler, Macon, Ga. Contractor, W. Z. Williams, Macon, Ga. Constructing Quartermaster, Lt.-Col. Walter L. Henwood.

Thirty-second Division.—Camp MacArthur, Waco, Tex. Contractor, Fred A. Jones Construction Company, Dallas, Tex. Constructing Quartermaster, Maj. Matthew Hanson.

Thirty-third Division.—Camp Logan, Houston, Tex. Contractor, American Construction Company, Houston, Tex. Constructing Quartermaster, Capt. W. P. Rothrock, M. Am. Soc. C. E.

Thirty-fourth Division.—Camp Cody, Deming, N. Mex. Contractor, J. W. Thompson Company, St. Louis, Mo. Constructing Quartermaster, Maj. Charles H. Miller, M. Am. Soc. C. E.

Thirty-fifth Division.—Camp Doniphan, Fort Sill, Okla. Contractor, Selden Breck Construction Company, St. Louis, Mo. Constructing Quartermaster, Lt.-Col. George D. Guyer.

Thirty-sixth Division.—Camp Bowie, Fort Worth, Tex. Contractor, J. W. Thompson, Dallas, Tex. Constructing Quartermasters, Maj. P. J. Van Zuben, and Lt.-Col. H. S. Baker, M. Am. Soc. C. E.

Thirty-seventh Division.—Camp Sheridan, Montgomery, Ala. Contractor, Algernon Blair, Montgomery, Ala. Constructing Quartermaster, Maj. A. W. Reynolds.

Thirty-eighth Division.—Camp Shelby, Hattiesburg, Miss. Contractor, T. S. Moody and Company, Chattanooga, Tenn. Constructing Quartermaster, Lt.-Col. W. J. Howard.

Thirty-ninth Division.—Camp Beauregard, Alexandria, La. Contractor, Stewart McGehee Construction Company, Little Rock, Ark. Constructing Quartermaster, Maj. A. M. Shaw, M. Am. Soc. C. E.

Fortieth Division.—Camp Kearney, Linda Vista, Cal. Contractor, W. E. Hampton Company, Los Angeles, Cal. Constructing Quartermasters, First Lieut. Charles Rogers, and Maj. C. H. Nichols, M. Am. Soc. C. E.

Forty-first Division.—Camp Fremont, Palo Alto, Cal. Contractor, The Lindgren Company, San Francisco, Cal. Constructing Quartermasters, Lt.-Col. W. G. Fleischauer, and Maj. J. B. Chaffey.

Disbursements: Auditing and Checking Procedure for Control of Disbursements.

To protect the Government in the expenditure of the vast sums involved, in such a short period of time, it was considered necessary to establish at each camp a Government Field Auditor, and, operating under him, an organization charged with the responsibility of approving all bills for material, labor, and expenses, before a Government check was issued to the Contractors.

All materials received on the grounds were checked as to quality by the Government checkers and inspectors. The invoices for such materials were compared with the original orders, as approved by Constructing Quartermasters, and a verification was made of prices and extensions.

The Government time checkers made a complete check of all the men working on the job two or more times every day, and, from such reports as were made, a check of the Contractor's pay-rolls was effected. The pay-rolls were further completely examined as to rates, extensions, and additions. The payment of wages was witnessed by Government representatives, and receipts were taken from the men in all cases.

All expendable and non-expendable materials received on the grounds—the latter item including tools, equipment, etc.—were accounted for under the system of Government property accounting, which is quite complete. Also, a close supervision was maintained of rented equipment, its condition on arrival, and if at any time the total rental paid to the Contractor equalled or approximated the value thereof, the equipment was taken possession of by the Government, with the payment of only such additional amount as was needed to give the Contractor the full value thereof.

A close check was kept on the arrival of carload shipments, unloading thereof, and prompt release of the cars, which automatically facilitated a settlement of freight and express charges with the railroad companies, and prevented demurrage charges.

The Field Auditor's organization also supervised the accounting for storerooms, commissaries, bunk houses, hospitals, etc. A list of Field Auditors is given in Table 5.

By adopting the form of emergency contract, and designing a special form of voucher, the Cantonment Division was able to reduce the accounting work to a minimum, considering the immense expenditures being made each day.

The Constructing Quartermaster was the disbursing officer, and was instructed as follows:

Payments.—The question of payments is one of the most vital in connection with the contract, especially that of the discount feature. Ordinarily, a statement is to be made up on the seventh of each month, and the contractor is to be paid on or about the ninth of each month. It will also be observed that the contract provides for interim payments, and in many cases it will be quite likely that it will be necessary to pay once in every 10 days. Each Constructing Quartermaster, therefore, should be in a position to pay for material the day it arrives, after it has been inspected and accepted, if the contractor satisfies the Constructing Quartermaster that such payment is necessary.

TABLE 5.—List of Field Auditors.

Camp.	Field Auditor.	Division Auditor.
National Army Camps.		
Devens	James F. Rollins	Robert Douglass
Upton	A. B. Dillon	David E. Boyce
Dix	W. P Elliott	David E. Boyce
Meade	E. L. Hatten	W. P. Hilton
Lee	E. A. Leitch	W. P. Hilton
Jackson	A. T. Holmes	Charles Neville
Gordon	S. J. Hayles	Walter Mucklow
Sherman	S. G. Rusk	Page Lawrence
Taylor	A. M. Trader	“ “
Custer	T. W. Betak	J. Porter Joplin
Grant	Edward B. McQuinn	“ “ “
Pike	Charles F. Bridewell	A. G. Moss
Dodge	John Mahony	Herbert M. Temple
Funston	H. S. Drake	“ “ “
Travis	Charles D. Block	Charles E. Wermuth
Lewis	H. E. Smith	Wm. Whitfield
National Guard Camps.		
Green	J. P. McDonald	Charles Neville
Wadsworth	T. W. Glaze	“ “
Hancock	H. F. Owens	“ “
McClellan	F. C. Horton	Walter Mucklow
Sevier	S. G. Sinden	Charles Neville
Wheeler	Tracy S. Newton	Walter Mucklow
MacArthur	A. A. Hart	Marion Douglass
Logan	G. H. Rathe	Charles E. Wermuth
Cody	J. Henry Wood	W. P. Musans
Doniphan	H. C. Crane	H. V. Robertson
Bowie	Charles Rowden	E. J. Archinard
Sheridan	L. S. Betty	G. G. Trost
Shelby	A. G. Moffat	Charles E. Wermuth
Beauregard	E. F. Hunter	A. G. Moss
Kearney	W. D. Ballantine	W. P. Musans
Fremont	H. E. Nowell	Wm. Whitfield

In order that the Constructing Quartermaster may be in a position to make prompt payments, the following plan will be followed:

At close of work each evening the Constructing Quartermaster will send a night telegram or night letter to the Contracting Office in Washington, stating his unobligated funds balance, and the amount of funds he requires, if any, in addition, to meet bills maturing the following day. On receipt of such telegram at Washington it will be immediately verified. A check for the amount requested will be sent to the Treasury by special messenger and the Constructing Quartermaster wired showing what funds have that day been placed to his credit. This will prevent accumulating idle funds to the credit of the Constructing Quartermasters, and will enable this office to transfer funds immediately to the point where they are required, in order to permit. when necessary, daily payments.

SUPERVISING ENGINEERS: THEIR DUTIES, AUTHORITY, AND COMPENSATION.

This is a subject that naturally interests the members of the Society, both from the standpoint of what the Committee at Washington recommended and the actual arrangements as carried out at different cantonments.

At the outset it should be made plain that the jurisdiction of the engineer at a cantonment was somewhat more restricted than would be thought, at first glance. Typical arrangements had already been designed in Washington, and further typical plans as needed would come from the same source. The contractor on the ground would doubtless carry more or less of an engineering organization of his own. In fact, on some of the work in April, 1917, the contractors did all the engineering.

The man in authority for the Government at the cantonment was the Constructing Quartermaster, and all engineers were junior to him. The opportunity, therefore, for engineers from civil life to jump to a contonment construction job on telegraphic notice and pursue customary civilian methods was entirely out of the question. Indeed, the most efficient civilian engineers on this work were those with a high coefficient of adaptability, who sought quickly to find out what the typical plans signified, as to intent on the part of the central office at Washington, and who then strove to fit such plans to workable construction procedures under widely varying conditions on the ground. Those who tried to force their individuality most strikingly to the front were by no means the most helpful.

They were unconscious of the handicap of not knowing what had been done and what was wanted at Washington, and they were seriously in the dark in regard to the availability of commandeered materials, and of the non-availability of materials as they knew of them prior to the war.

The Committee on Engineering reported that engineering work at the cantonments might be done in one of three methods, as follows:

1.—By utilizing existing engineering organizations with competent staffs capable of ready expansion, through which all the engineering services required at the cantonment would be rendered. The head of this organization would become Supervising Engineer, or Superintendent of Construction, acting under the general direction of the Constructing Quartermaster resident on the work.

2.—By the organization of the entire local engineering force *de novo,* from top to bottom, under the immediate supervision, rather than direction, of the Constructing Quartermaster resident on the work. The engineers thus drawn to the aid of the Constructing Quartermaster would then be compensated on a salary basis, in some cases as Reserve Corps Officers.

3.—By a combination of Methods 1 and 2, that is, by the organization of a local engineering force under the direction of the Constructing Quartermaster supplemented by the utilization of existing engineering organizations in special branches of the work, such as water-works, sewerage, site and city planning, etc.

The Committee recommended that the first of these plans was best and cheapest, on the basis that it would save time for organization, promote increased efficiency, and allow existing engineering organizations to be strengthened rather than impaired—to the present and future advantage of the country. Under this plan it was proposed to pay the engineering organization the actual cost of its assistants, with traveling and other expenses, plus a percentage on the entire cost of a cantonment of three-quarters of 1 per cent. It is understood that two or three engineering contracts of this type were executed, but with a lump sum maximum fee stipulated as perhaps from $30 000 to $40 000, as in June it was thought that the cantonments would not cost more than about $5 000 000 each.

The third method, that is, the Constructing Quartermaster building up his own staff from engineers of the Reserve Corps and other civilian engineers, reinforced by an experienced water-works engineer, was the one which was apparently most popular. It is understood that the engineers who looked after water-works and sewerage matters received, for their own services and the disturbances which this Government work produced in their private offices, fees of about $7 500, or perhaps 1½%, or a little more, of the then estimated cost of such construction work. In some instances engineers supervised not only water-works, sewers, and sewage disposal, but did a good deal of surveying work, laying out of roads, and the like. It is understood that some of the fees approached $15 000, and hence represented an intermediate class between those described under Methods 1 and 3. In a majority of cases the engineers did considerably more work than their contracts called for.

The fees paid to Supervising Engineers for their services at the National Guard Camps ranged from $2 500 to $4 000. No town planner was assigned for the National Guard Camps. The general layout plan formulated in the Washington Office was adapted to the topography by the Supervising Engineer.

In speaking of Method 1, it is probably a fact that the engineering organizations, following the outbreak of the war and the completion of work then in hand, did not hold together as well as was anticipated. By that it is meant that the young men of our profession, in a great many instances, showed a keen desire to get quickly into some branch of the military establishment, and hence many engineering organizations soon found themselves comparatively stripped of the younger members of their staffs. How much this had to do with the style of engineering organization actually engaged on the field work of cantonment construction is not known.

The Committee at Washington fully realized the importance of having experienced practical construction men on this work, and recommended that salaries be paid according to a schedule, as follows:

Principal Assistant Engineers..........	up	to	$350	per	month.
Assistant Engineers and Designers......	"	"	250	"	"
Instrumentmen and Draftsmen..........	"	"	175	"	"
Junior Draftsmen and Secretarial Assistants	"	"	125	"	"
Assistants	"	"	90	"	"

Undoubtedly there were cases where Supervising Engineers got men to act as Assistant Engineers who gave up salaries far greater than those which the Constructing Quartermaster could approve. In some instances the assistant engineers were in such circumstances that they could not make too great financial sacrifices, and in such cases the Supervising Engineers lessened their own net fees by making up deficits in salaries out of their own pockets for assistants possessed of high qualifications for pushing the work to completion at such an enormous rate of speed.

The Committee also spent considerable time in drafting forms of contract for these and other branches of engineering services, including work on docks, storage warehouses, etc. Forms of contract at percentage fees, such as engineers in private practice are accustomed to, did not get very far, although they were the subject of numerous conferences in May and June, and of some special conferences in August. The real difficulty seems to be that at first civilian engineers are of limited aid because they do not know enough about the exact requirements of the military establishment, materials that have been or can be commandeered, and other information such as has been well digested in the Washington office of the Cantonment Division. In other words, a civilian engineer is not necessarily in a position to design emergency work advantageously for the War Department beyond advising perhaps on some special phases.

When it comes to the execution of construction work he becomes junior to the Constructing Quartermaster, unless he is prepared to join the service and fill that office himself. Furthermore, his field tasks may not be lightened by the contractor carrying an engineering organization of his own, especially equipped for the work in hand and capable of doing work which will speak for itself with the Constructing Quartermaster.

Hence the civilian engineer who goes to Washington with a record of successful accomplishments for railroads, municipalities, water companies, and the like, may meet disappointment. Emergency construction work for the Government calls for high-grade engineering, but with methods quite different from that encountered in peace-time pursuits of civil life.

Personnel of Supervising Engineers and Town Planners.

Within the past few years much has been heard of correct town planning. It is interesting to note that the planners were given ample opportunity to offer practical advice in securing preliminary information as to the best way of adapting the various structures of a cantonment to the widely varying topographical conditions found at the different sites. The town planners also were retained to advise on the permanent camp layout.

The personnel of the Supervising Engineers and Town Planners is given in Table 6.

TABLE 6. List of Supervising Engineers and Planners.

Camp.	Supervising Engineers.	Town Planners.
National Army Camps.		
Devens	Frank A. Barbour, M. Am. Soc. C. E.	H. J. Kellaway.
Upton	Walter E. Spear, M. Am. Soc. C. E.	F. Vitale, Jr.
Dix	Allen Hazen, M. Am. Soc. C. E.	Charles W. Leavitt, M. Am. Soc. C. E.
Meade	Morris Knowles, M. Am. Soc. C. E.	Owen Brainard, M. Am. Soc. C. E.
Lee	Allen J. Saville, Assoc. M. Am. Soc. C. E.	J. L. Greenleaf.
Jackson	P. H. Norcross, M. Am. Soc. C. E.	Richard Schermerhorn, Jr., M. Am. Soc. C. E.
Gordon	Robert E. Barnwell.	Charles W. Lowrie.
Sherman	R. Winthrop Pratt, M. Am. Soc. C. E.	Warren H. Manning.
Taylor	James B. Wilson, Assoc. M. Am. Soc. C. E.	H. P. Kelsey.
Custer	Samuel A. Greeley, Assoc. M. Am. Soc. C. E.	Thomas W. Sears.
Grant	Alvord and Burdick, Members, Am. Soc. C. E.	E. H. Bennett.
Pike	E. B. Black, M. Am. Soc. C. E.	L. V. Sheridan, Assoc. M. Am. Soc. C. E.
Dodge	Louis P. Wolff, M. Am. Soc. C. E.	Robert Wheelwright.
Funston	Wynkoop Kiersted, M. Am. Soc. C. E.	J. S. Pray and S. Herbert Hare.
Travis	Robert J. Harding, M. Am. Soc. C. E.	George E. Kessler and E. N. Noyes, M. Am. Soc. C. E.
Lewis	William J. Roberts, M. Am. Soc. C. E. R. H. Thomson, M. Am. Soc. C. E.	Charles F. Pilat.
National Guard Camps.		
Green	J. L. Ludlow, M. Am. Soc. C. E.	
Wadsworth	J. E. Sirrine, M. Am. Soc. C. E.	
Hancock	Nesbit Wingfield, M. Am. Soc. C. E.	
McClellan	Morris Knowles, M. Am. Soc. C. E.	
Sevier	J. E. Sirrine, M. Am. Soc. C. E.	
Wheeler	G. R. Solomon, M. Am. Soc. C. E.	
MacArthur	J. B. Hawley, M. Am. Soc. C. E.	
Logan	E. E. Sands, M. Am. Soc. C. E.	
Cody	Black and Veatch, Members, Am. Soc. C. E.	
Doniphan	Black and Veatch,	
Bowie	F. J. Van Zuben.	
Sheridan	G. G. Earle, M. Am. Soc. C. E.	
Shelby	Twombley and Hemphill.	
Beauregard	W. R. Gross.	
Kearney	Louis C. Hill, M. Am. Soc. C. E.	
Fremont	G. A. M. Elliott, M. Am. Soc. C. E.	

CONSTRUCTION ACCOMPLISHMENTS: DATES, QUANTITIES OF MATERIALS, PROGRESS, AND COSTS.

On June 15th, the date when the Appropriation Bill was signed, the first contract for cantonment work was signed, and work was begun. The last of these contracts was signed on June 27th, the date when the last camp site was officially adopted. Construction work on the last cantonment was under way on July 6th.

So much has appeared in the daily and technical press as to these army camps that it is hardly worth while to say a great deal about the quantities of materials required for building some 1 500 structures at each site. The uniqueness of the undertaking is to be found in the quantity, and not in the quality, of the structures.

In brief summary, it may be well to note the approximate quantities of some of the principal materials used in building the 16 National Army camps, as follows: Lumber, 809 238 000 000 ft., b. m.; roofing paper, 8 029 780 000 sq. ft.; water-closet bowls, 53 936; radiation, 4 222 016 sq ft.; wood stave pipe, 1 023 248 ft.; cast-iron pipe, 468 290 ft.; wire (all kinds and sizes), 5 458 miles; wood tanks (aggregate capacity), 8 300 000 gal.; fire hose, 392 500 ft.; kitchen stoves and ranges, 9 825; garbage incinerators (capacity), 355 tons; garbage cans, 54 721; cots, 720 548.

The corresponding materials used in the 16 National Guard camps, for the troops housed under canvas, may be compared, as follows: Lumber, 302 590 000 000 ft., b. m.; wood pipe, 148 838 ft.; cast-iron pipe, 513 088 ft.; steel pipe, 524 800 ft.; wire (no inside wiring), 1 508 miles; wood, concrete, and steel tanks (aggregate capacity), 3 050 000 gal.; fire hose, 127 500 ft.

Colonels Whitson and Junkerfeld proved efficient stimulating administrators of the field work of the Cantonment Division. They were of great aid to Constructing Quartermasters and also to Contractors. They did much to put things right, at times and places where organization arrangements were not best adapted to local needs. They had assistants who brought data to the Washington office, where other experienced engineers were engaged in tabulating the records of performances, as telegraphed by the Constructing Quartermasters, and checked by those who were practically traveling inspectors from the Washington office.

The 16 National Army cantonments were listed at frequent intervals in percentages of actual accomplishments, as compared with the total expected at the commencement of construction.

On September 3d, out of a possible 80% of maximum completion by the items considered, the percentage standing of the several army cantonments was as follows: Camp Taylor, 79.4; Camp Travis, 78.6 (August 31st); Camp Lee, 78.5; Camp Devens, 74.0; Camp Lewis, 72.0 (August 31st); Camp Sherman, 70.0; Camp Pike, 67.0; Camp Grant, 66.0; Camp Jackson, 60.0; Camp Funston, 59.0; Camp Gordon, 57.0; Camp Dix, 55.0; Camp Custer, 51.0; Camp Dodge, 50.0; Camp Meade, 37.0; Camp Upton, 28.0.

The work above the maximum 80% listed in these ratings consisted of roads, hospitals, remount facilities, additional trains, and extensions not contemplated by the contracts at the commencement of construction. The various inspectors connected with this work in the Washington office and elsewhere resorted to all the expedients that they could think of to increase the speed of construction, and to stimulate rivalry between the cantonments. The ratings were posted and discussed like baseball averages, on the hypothesis that the 16 camps corresponded to the teams in the American and National baseball leagues.

Although it is apparent that speed was retarded by overtaxed transportation facilities, congested labor markets, difficulties in housing the laborers, and extent of work to be done in clearing some of the camp sites of trees, etc., the main thought to record is that on September 4th it was possible to house about 430 000 of the total 650 000 conscripted men in the first draft, and to send the drafted men to camps, as had been provided, the first 5% to arrive on September 5th, followed by 40% on September 19th, 40% on October 5th, and 15% thereafter.

On November 30th, at nearly all the camps, there was substantial completion of the original construction work, plus many betterments ordered during the construction period. This state of substantial completion was reached much earlier at some camps than at others, but by December 20th, 1917, all contract work was closed; and such remaining betterments as were required, if any, were to be completed by the Camp Quartermasters. This is a wonderful record of emergency construction work.

The cost of construction of the several cantonments and National Guard camps, with a few estimated items, has been published in the technical press and need not be repeated here in detail. The total costs, under the different classifications of the Quartermaster General's office, taken from published figures*, and but slightly modified by official figures compiled under date of March 5th, 1918, are given in Table 7.

TABLE 7.—COST OF CONSTRUCTION OF SIXTEEN ARMY CAMPS OF EACH TYPE.

	National Army Cantonments.	National Guard Camps.
Barracks and quarters	$71 213 495	$15 617 108
Supplies, services and transportation	50 067 017	10 997 342
Roads, walks, wharves and drainage	8 036 271	3 859 523
Shooting galleries and ranges	797 241	1 696 507
Construction and repair of hospitals	10 159 333	7 502 651
Military post exchanges	453 115	....
Total personnel	654 786	438 042
Cost per capita	214.92	87.60
Total of above costs	$140 726 472	$39 673 131
Official totals, as of March 5th, 1918	140 856 991	38 750 506

WATER SUPPLY.

Great care was taken to make arrangements for an absolutely safe water supply, from a sanitary standpoint, not only for the main camp uses, but also for the construction forces.

The quantity of water needed at the cantonments was an uncertain item, and received extended discussion by the Committee at Washington, as well as by officers and engineers of the Cantonment Division. It was concluded to allow at the cantonments 55 gal. per capita per day, which is equal to a net allowance for the use of the men of about 50 gal. per day, and 15 gal. for each horse and mule, on the assumption that there would be about one animal for every three men. This is about 80% more water, on an average, than is supplied to European army camps, and was considered a reasonable allowance, if care was taken to use it in the manner described in the "Instructions to the Constructing Quartermasters."

It was assumed that the peak load for a period of 1 hour might become 2.85 times as great as the average, or, say, at the rate of 5 000 gal. per min. for 1 hour for a cantonment of 45 000 men. Obviously, this means that water for shower baths, road sprinkling, and animal uses, must be on a basis of rotation and not of coincidence; and that great care must be exercised to guard against needless wastage through unclosed or leaky fixtures.

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* *Engineering News-Record,* March 21st, 1918.

The pressure of the water supply as it entered the mains of the cantonments was intended to be within the range of 60 to 85 lb. per sq. in. Fire protection was kept in mind concerning the lower limits, and the higher limit was restricted to the figure stated, because of the necessity of using wood-stave pipe, in the interests of speed and economy. The main feeders, 10 or 12 in. in diameter, were looped ordinarily, so that, in case of fire, the water could be drawn from each direction through main lines, and this tended to lessen the size of mains for the given range in pressures, in accordance with the skillful studies of Lt.-Col. D. H. Maury, M. Am. Soc. C. E., Maj. Clarence Goldsmith, M. Am. Soc. C. E., and Mr. W. M. Johnson. The largest pipes were 16 in. in diameter.

The water supply was taken from neighboring cities where practicable, as at Camps Gordon, Jackson, Lee, Pike, Taylor, and Travis. At Camps Dix and Meade, efforts were made to secure ground-water, but without success. At the former, the supply is taken from Rancocas Creek, and sterilized. At Camp Meade the water is taken from the Little Pautuxent River, filtered and sterilized. For the remaining camps, the supply was developed from open wells or, more generally, from driven wells in water-bearing strata in the vicinity of the cantonments.

The cost of the water supplies at the cantonments, including service connections to within 5 ft. of the buildings, was less than $11 per capita, or, roughly, one-fifth of the cost new for the average municipal water-works system. Part of this reduction is explained by the density of the population in the camps and partly by the fact that about 70% of the distribution mains were of wood-stave pipe costing only about 60% of that of cast-iron pipe. On the whole, the construction cost of the water-works is believed to be highly creditable.

As to plumbing, discussion in Washington was given to self-closing faucets to guard against waste, but this suggestion was not carried out. In fact, to get plumbing supplies as promptly as needed, there was, apparently, some sacrifice in quality, as it is understood that the plumbing is lighter than would prove desirable in some cases. For instance, the humic acid contained in the swampy waters flowing at times in Rancocas Creek is understood already to have produced serious corrosion of some of the plumbing fixtures at Camp Dix.

As to the adequacy of the water supply in point of quantity, proof is yet to be obtained, with the use of shower baths during the coming summer.

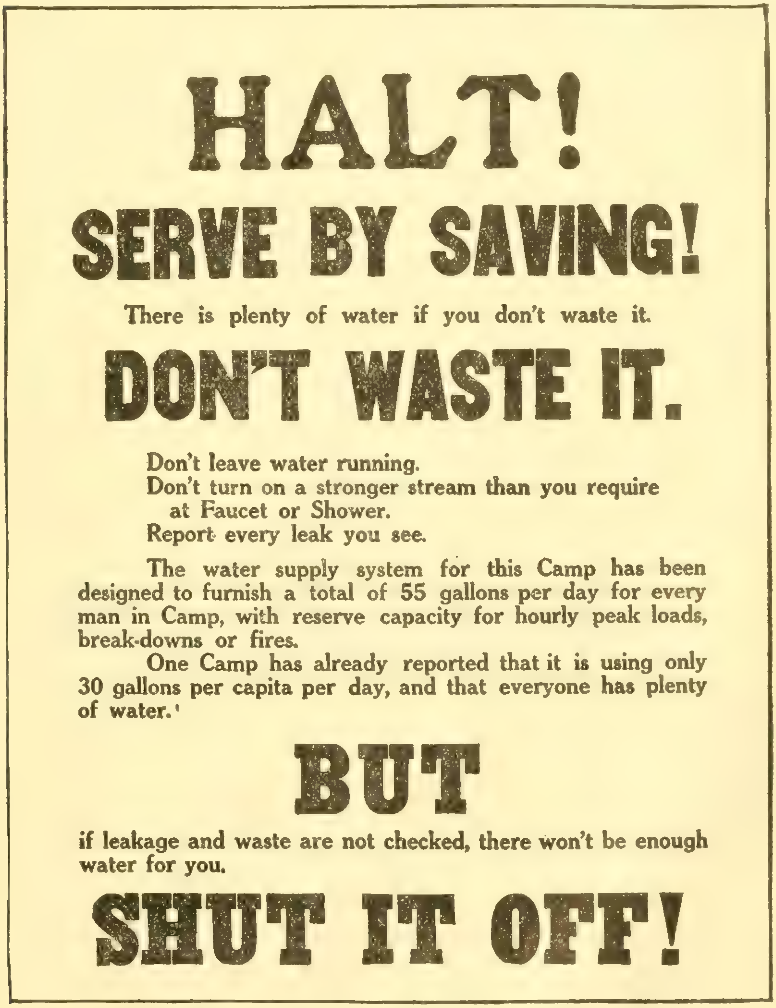
It is stated that the water consumption at some of the camps has exceeded 55 gal. per day in instances where gravity supplies in ample quantities are available. The checking of waste, as the advancing season calls for a more general use of shower baths, will make it important to place the use of water on a strictly military basis, as the designers of the system intended when they prepared their basic data as to quantity and when this was supplemented by posters (Fig. 1) displayed in the cantonment lavatories.

In the National Guard camps the water supply was estimated on the basis of 35, as compared with 55 gal., per capita daily for the cantonments. The Guard camps were not begun until about the end of June, and were intended to be completed about the first of September. The structures of wood were limited to storehouses, mess halls, kitchens, and showers, and did not warrant so elaborate a waterworks system as the cantonments. In the latter, water pipes up to 16 in. in diameter were used, whereas at the Guard camps all distribution mains are 6 in. in diameter. At eleven of the eastern camps the mains were of wrought steel; at two near the Birmingham District they were of cast iron; and at those near the Pacific Coast they were of wood staves.

It is to be borne in mind that much of the pipe for the distribution mains had been ordered and was on the cars before any construction was done at the camp sites. Storage reservoirs on convenient hills were built where practicable, and of a capacity ranging from about 250 000 to 1 200 000 gal. Where the topography did not admit of storage reservoirs, elevated wood tanks, of 200 000 gal. capacity, were erected at as favorable elevations as practicable.

Pumping is generally done by electricity, with a gasoline or oil-engine standby to guard against interruption to service through failure of the electric current.

Practical Elimination of Water-Borne Diseases Among American Troops, from September, 1917, to March, 1918. The best credential as to the quality of the water supplied at the army camps is recorded by the vital statistics of water-borne diseases among the troops, on the well-known basis that "the proof of the pudding is in the eating." At the end of March, the following statement was issued from the office of the Surgeon General of the Army:



HALT!

SERVE BY SAVING!

There is plenty of water if you don't waste it.

DON'T WASTE IT.

Don't leave water running.
Don't turn on a stronger stream than you require at Faucet or Shower.
Report every leak you see.

The water supply system for this Camp has been designed to furnish a total of 55 gallons per day for every man in Camp, with reserve capacity for hourly peak loads, break-downs or fires.

One Camp has already reported that it is using only 30 gallons per capita per day, and that everyone has plenty of water.'

BUT

if leakage and waste are not checked, there won't be enough water for you.

SHUT IT OFF!

FIG. 1.—POSTER DISPLAYED IN EACH NATIONAL ARMY CAMP LAVATORY. THE ORIGINAL WAS 11 BY 14 IN., WITH THE LARGER LETTERS PRINTED IN RED.

"We have had practically no typhoid among troops, except within the first two or three weeks following their entry into the service, and infection in most cases had been contracted prior to their coming to camp. In a general way, we are safe in saying that water-borne diseases are now practically eliminated."

The official statistics show 121 cases and 6 deaths from typhoid fever and 289 cases and 2 deaths from dysentery in the army camps in the United States for 22 weeks from September 29th, 1917, to March 1st, 1918, and it is certainly gratifying to know that these two diseases are now eliminated, as far as the responsibility of the public water supply is concerned. It should be pointed out that the annual death rate from typhoid fever approximates 1 per 100 000 as compared with annual rates of from 5 to 15 for the ordinary American city having a good, or fairly good, water supply.

Each week the Surgeon General's office issues statistics showing the prevalence of special diseases among all troops in this country, and also the expeditionary forces abroad. A recent statement of the case rate of special diseases is given in Table 8.

TABLE 8.—ANNUAL CASE RATE PER 1 000 FOR SPECIAL DISEASES.

	All troops in U. S., week ending March 22d, 1918.	Regulars in U. S., week ending March 22d, 1918.	National Guard. All camps, week ending March 22d, 1918.	National Army. All camps, week ending March 22d, 1918.	Expeditionary Forces, week ending March 14th, 1918.
Pneumonia....	23.5	22.4	11.9	33.3	36.2
Dysentery.....	0.1	0.0	0.0	0.3	0.7
Malaria........	1.9	0.8	4.5	0.9	0.0
Venereal.......	78.5	85.9	39.4	95.3	46.0
Paratyphoid...	0.04	0.0	0.0	0.1	0.0
Typhoid.......	0.1	0.0	0.0	0.3	0.2
Measles........	34.4	37.9	4.0	48.6	16.5
Meningitis.....	1.6	1.6	0.6	2.3	2.5
Scarlet Fever..	11.1	13.0	3.6	12.3	30.9

It is hardly necessary to state that in earlier wars, typhoid fever caused the death of large numbers of men. Thus, in the Franco-Prussian War of 1870-71, the total number of cases of typhoid fever among the under officers and men in the German Army amounted to 73 396, which is equivalent to 9.3% of the average strength of the army. The relation of cases to deaths is not known, but, ordinarily, the latter are about 10% of the former. The ratio naturally varies with numerous local factors.

During the Spanish-American War, in 1898, conditions were unusually distressing in regard to the prevalence of typhoid fever among the American troops. Lack of proper camp hygiene, with transmission of disease germs by flies from latrines to the food in the kitchens and mess tents, was the principal cause, rather than the "embalmed" beef, about which so much was written at the time.

The figures in Table 9 of the official typhoid fever statistics of the American Army of 1898, are of interest.

TABLE 9.—Typhoid Fever Record of Different Corps of American Army in the Spanish-American War, 1898.

Camp.	Number of regiments.	Mean strength.	Cases of Typhoid Fever.		Deaths from typhoid fever.	Deaths from all diseases.
			Certain.	Certain and probable.		
Chickamauga	22	27 330	2 912	5 921	344	397
"	17	20 568	1 741	4 418	417	469
Tampa	7	7 507	440	1 498	99	112
Alger	18	19 807	1 807	2 226	212	259
Meade	12	13 962	1 799	2 690	150	168
Jacksonville	9	10 759	1 729	2 693	248	281
"	7	7 990	......	1 292	120	146
Total	92	107 973	10 428	20 738	1 580	1 832

More than 90% of the men who developed typhoid fever had no preceding intestinal disorder. The deaths from typhoid fever were 86.24% of the total deaths. The morbidity, or case rate, from typhoid fever was a little less than one-fifth, or 192.65 per 1 000 of mean strength. The mortality from typhoid fever per 1 000 of mean strength was 14.63.

No citizen, and particularly no sanitary engineer, can view the statistics in Table 9 without a shudder, or without expressing the sincere hope that there will be no cessation during the present war in the effort to provide safe water for the troops, to put in screens promptly, and to see that the present latrines, where in use, are maintained in a sanitary condition, or superseded by sewerage works.

Vaccination against typhoid fever, of course, is a helpful factor now, and is worthy of mention.

Fire Protection.

The need for rapid construction, and the limitations of cost to provide cantonments for the National Army, made the use of wooden buildings the only practicable solution of the problem. The number of such buildings required at each cantonment (about 1 700) resulted in a sizeable city of wooden buildings, so that the question of fire protection was of much importance. Early consideration was given to this phase of the cantonment problem, with the aid of Messrs. Clarence Goldsmith and W. M. Johnson, loaned from the engineering staff of the National Board of Fire Underwriters. A general programme was adopted, which included the following salient features:

(*a*).—General provision for separating or spacing main buildings so that a fire would ordinarily involve only the one building in which such fire originated. In addition, well-defined clear spaces in which no buildings were to be erected, were designed as firebreaks; across these it was reasonable to assume that even a fire involving a considerable number of buildings would not communicate.

(*b*).—Construction requirements which tend to reduce the hazard of fire starting within the buildings, principally in prescribed regulations for setting stoves, ranges, and heaters, and for having all electrical work done in accordance with the National Electrical Code.

(*c*).—A water-supply system designed to deliver water throughout most camps at a sufficient pressure to supply good streams for fire fighting directly from hydrants, and with hydrants placed so that 16 streams could be concentrated on any of the large barrack buildings, with lines of hose, none of which would exceed 500 ft. in length.

(*d*).—The distribution of first-aid fire extinguishing apparatus throughout all buildings, these to include fire-pails, chemical extinguishers, water barrels, and hand-pump tanks.

(*e*).—The distribution of hand-hose carts, each carrying 500 ft. of fire hose and equipment for use of regimental fire brigades. It is thought that, owing to the training and discipline of troops occupying these camps, regimental fire brigades form a powerful auxiliary fire fighting force, and though they may not get into operation as quickly as the technical fire company, they form a large reserve from which units may be drawn in case of serious fires.

(*f*).—A military fire company, recruited from men having training in paid fire departments, this company to be stationed at three or more fire houses, and equipped with motor fire trucks, carrying all the usual equipment of a city fire department. Such companies have been authorized for all the National Army and some of the National

Guard camps, and include a personnel of one commissioned officer, 7 non-commissioned officers, and 36 men.

(*g*).—Provision for fire-alarm service, consisting of special telephones distributed throughout the camp, and accessible at all times, over which fire-alarms can be sent to the telephone exchange from which such alarms are transmitted to the fire-stations by telephone, and a special fire-alarm gong circuit of usual fire-alarm direct type. A large siren for general notification of the entire camp was also included.

(*h*).—In division storehouses, additional protection in the way of automatic fire-alarm systems have been provided.

During the construction of the 16 National Army cantonments, an engineer of the National Board of Fire Underwriters was detailed to each camp, to act as Advisory Engineer and Fire Marshal for Constructing Quartermasters. Fire prevention regulations were included in the instructions to Constructing Quartermasters.

Of course, all this protection was not available during the early steps of the construction work, when temporary organizations of fire companies, equipped with motor trucks carrying small fire appliances, were put into service. A thorough system of guard and watch, one feature of which at a number of camps was a watch from an elevated tower overlooking the entire camp site, was also maintained.

Regular inspections for fire prevention were made by members of the temporary fire companies and fire marshal and by the fire prevention engineers.

The result of this campaign of fire prevention, and the attention given to fire protection during construction, was that no fires of serious consequence occurred in the National Army cantonments during the construction period. The total property loss during the strictly construction period is estimated to be about $2 000. In the construction of the National Guard camps, there was only one fire of any consequence during the construction period, this involving a loss of about $15 000.

The cost of the permanent features of fire protection at a typical National Army cantonment, not including cost of water supply, is given in Table 10.

TABLE 10.—FIRE EQUIPMENT AT CAMP GRANT.

Fire stations (1-story) for use of men and apparatus	3	$20 000
Automobile fire-trucks	6	11 000
Cotton rubber-lined fire-hose	25 000 ft.	16 250
Hand-hose carts, with equipment	38	3 230
Extinguishers, 2½ gal	150	1 462
Extinguishers, 1 qt	150	750
Hand pump tanks	830	4 150
Fire-pails	10 300	3 090
Water barrels	400	1 000
Fire-alarm gong-signal system	....	1 500
Miscellaneous and sundry equipment	....	3 000
Building hose-reel houses, shelves and brackets for fire appliances	....	3 000
Total	....	$68 432

At the 16 cantonments there were 75 miles of fire-hose and 3 550 hydrants.

SEWERAGE AND SEWAGE DISPOSAL.

At each cantonment a system of sewers was built for the removal of house sewage only. Surface drainage was not admitted to the sewers intentionally, except perhaps in some special instances. Open ditches were suggested for drainage, with brush or other simple means of protection against erosion, and with corrugated-iron culverts at street crossings.

At each cantonment the house connections, practically to the buildings, were 6 in. in diameter, with the exception of a few 4-in. kitchen connections. Grease traps, 18 in. in diameter, were included in the plumbing arrangements. No special construction features on the sewers are worthy of note, except that in wet soil there was an unusual attempt made to prevent infiltration of ground-water, and in the vicinity of trees, much care was taken to prevent the intrusion of roots in the pipes.

Ordinary minimum velocities of flow were provided, and much study was given to the effect of maximum flow, especially in its relation to combinations of varying numbers of regimental units.

At the National Guard camps, little was done with regard to sewerage systems, but latrines were provided for the most part, as was the case at the Mexican border. It is understood that soil conditions at some of the camps are not favorable for long-continued use of latrines, and this is a question needing prompt review and suitable action.

General Specifications.—About the middle of June general specifications and typical plans, as to sewage disposal were provided for inclusion in the general instructions issued to Constructing Quartermasters, as follows:

(1).—Where practicable, sewage will be discharged directly into adjoining streams without treatment.

(2).—Where sewage treatment is required, single-story septic tanks will be used, designed on the basis of a gross capacity of about 10 gal per capita; the entire capacity below the flow line being considered to be the gross capacity.

(3).—The arrangement of the tanks will conform in general to the typical plans, but grit chambers will not be provided except in special cases. These plans show both wood and concrete tanks, and the decision will be made at each cantonment as to whether one or the other will be used, preference being given, other things being equal, to the material that will enable the tanks to be completed in ample time for the service requirements.

(4).—No provision will be made for sludge beds, on account of lack of funds, and also because of lack of immediate need for these beds, which, however, will be required later. The disposal of the sludge may be best accomplished in the interval by machine trenching, or hand trenching if necessary.

(5).—At Ayer, Mass., and Wrightstown, N. J., sand filtration appears to be necessary, and the decision will be made by the Constructing Quartermaster as to whether or not tankage shall precede sand filtration.

(6).—Where cantonments are not near large streams, as referred to in Paragraph (1), and excepting the locations specified in Paragraph (5), trickling filters will form part of the complete installation, although not to be constructed immediately. These filters will have beds 6 ft. in depth, designed on a basis of 30 000 persons per acre. In general, the plans for trickling filters will conform to the typical plans; the details, however, must be decided by the Constructing Quartermaster, to suit local conditions.

(7).—Septic tanks shall be not less than 300 ft. from the nearest barrack or other occupied building, and at a greater distance, if practicable.

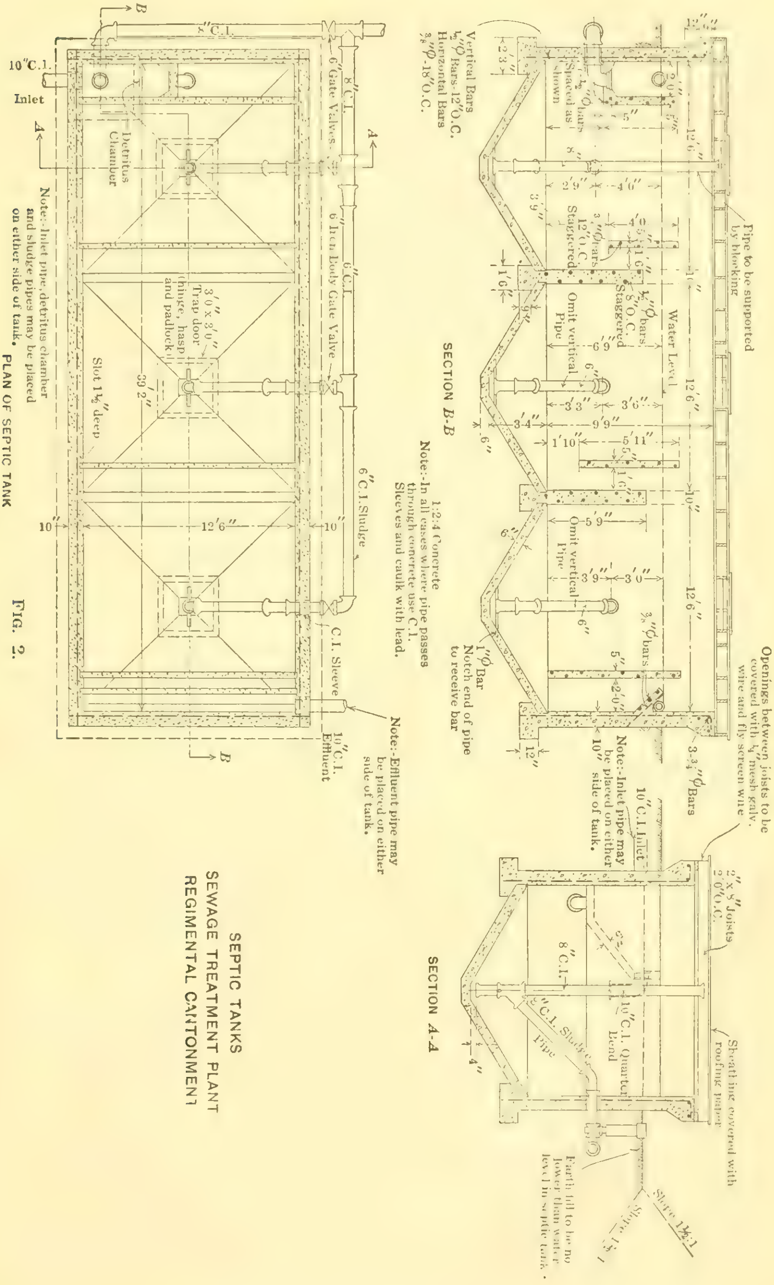
(8).—The elevation of the septic tank, with reference to the available outlet for the effluent from the sewage disposal works, should be such that the vertical distance between the flow line in the tank and the outlet of the trickling filter effluent drain is about 15 ft. In places where the effluent discharges into streams which ordinarily contain clear water, or only very little water, it will be necessary to provide in addition small settling tanks to clarify the effluent from the trickling filters, and these will require about 1 ft. of additional head. Such tanks should be designed to have a capacity of 3 gal. per capita. Sludge from these tanks will be disposed of on sludge beds later to be provided, or in trenches.

(9).—Except where sand filters are used, automatic chlorinating apparatus is to be provided at all sewage treatment plants as part of the original installation, and such apparatus is to be used whenever required. On account of cost, and for other reasons, treatment by ultraviolet rays is not to be considered.

Fig. 2 shows the typical details of the standard single-story septic tank adopted for use at cantonments. This is not in line with recent practice for some municipal sewage treatment plants, and requires some description as to the surrounding circumstances. It represents the views and experience of Maj. L. S. Doten, M. Am. Soc. C. E., Quartermaster General's Office, for many years in charge of sewage disposal plants at army posts.

Discussion at Washington last year led promptly to the selection of a single-story tank from 10 to 12 ft. deep, as compared with the more customary two-story tank of much greater depth. It was recognized at once that, at sites of unknown conditions as to soil, there would be much greater likelihood of having built by September a shallow as compared with a deep tank, particularly if the excavation were to be in wet running sand or in rock. It was reasoned that a single-story tank actually built would be infinitely superior to a two-story tank unavailable until the following spring. Furthermore, it was recognized by those at Washington that camp sewage would contain much more coarse, uncomminuted suspended matter, such as toilet paper, particles of feces, and débris from the kitchens, than is the case with ordinary city sewage after having had an opportunity to become comminuted by flowing for some miles in a relatively long system of sewers. Grease is also a very large factor in the composition of fresh camp sewage.

Hence, a settling tank at these cantonments would face "flotation" rather than "sedimentation" conditions, to a large extent, when account


PLAN OF SEPTIC TANK
10" C.I. Inlet
8" C.I.
6" Gate Valves
8" C.I.
Detritus Chamber
6" Iron Body Gate Valve
6" C.I.
3'0" x 3'0" Trap door (hinge, hasp and padlock)
Slot 1½" deep
39'2"
12'6"
10"
6" C.I. Sludge
C.I. Sleeve
10" C.I. Effluent
Note:-Inlet pipe, detritus chamber and sludge pipes may be placed on either side of tank.
Note:-Effluent pipe may be placed on either side of tank.
SECTION B-B
Vertical Bars ½"φ Bars-12"O.C.
Horizontal Bars ⅜"φ-18"O.C.
½"φ bars Spaced as shown
Pipe to be supported by blocking
Water Level
¾"φ bars 12"O.C. Staggered
½"φ bars 8"O.C. Staggered
Omit vertical Pipe
12'6"
9'9"
10"
3'-4"
1'10"
5'11"
5'9"
3'9"
3'0"
3'3"
3'6"
6'9"
2'9"
4'6"
1'6"
⅜"φ bars
1"φ Bar Notch end of pipe to receive bar
Openings between joists to be covered with ¼" mesh galv. wire and fly screen wire
3-¾"φ Bars
12"
Note:-Inlet pipe may be placed on either side of tank.
1:2:4 Concrete
Note:-In all cases where pipe passes through concrete use C.I. Sleeves and caulk with lead.
SECTION A-A
2"x 8" Joists 2'0" O.C.
10" C.I. Inlet
8" C.I.
10" C.I. Quarter Bend
6" C.I. Sludge Pipe
Sheathing covered with roofing paper
Earth fill to be no lower than water level in septic tank.
Slope 1½:1

SEPTIC TANKS
SEWAGE TREATMENT PLANT
REGIMENTAL CANTONMENT

FIG. 2.

is taken of what practice reveals as to the influence of grease and the buoyancy of relatively coarse suspended particles commingled with entrained gas. That is to say, with a deep two-story tank, as with a shallow single-story, there is a strong likelihood that most of the solid matter, at times at least, would be in the upper rather than in the lower portion of the tank.

With either type of tank, moderate success is to be expected with adequate and skillful operation, but in neither case, without such operation, is failure surely to be avoided. Efficient operation means adequate labor, and facilities for sludge removal, which cannot be put off indefinitely either in tanks as built or in tanks several times as large. See Paragraph (4) of the foregoing specifications, showing sludge beds or trenches to have been excluded from the 1917 programme.

Much discussion was given to building the tanks of wood where that would be quicker than concrete construction. Wood was used at Camp Dix, where the baffles were omitted except at the ends of the tanks. The purpose of the baffles is to hold back solid matters, especially at times of high peak flows, which are characteristic of camp sewers.

Sanitary engineers have debated the use of so many baffles, the intent of which is to keep the solid matters from reaching the outlet and to allow of liquid chlorine to be applied in the last compartment at those camps where, for the present, neither sand or trickling filters have been provided.

The trickling filters at Camp Meade, and perhaps at some other camps, were not built in 1917, and will apparently need consideration in 1918, if the arrangements are to approach those required of many municipalities. Grease recovery has been attempted at Camp Dix.

GARBAGE AND REFUSE DISPOSAL.

At each kitchen all waste material is sorted and placed in separate cans, thereby making a complete separation. By this means, all the various materials, such as garbage, bones, fats, grease, paper, tin cans, and bottles are rendered marketable.

In handling garbage, the two-can system was adopted. When filled cans are removed from the kitchen, they are replaced with clean ones. All cans are provided with close-fitting covers. These cans are placed in Government trucks and removed to a transfer station under the supervision of sanitary inspectors. The contents of the cans are then dumped into the contractor's trucks. The transfer station consists of platforms and storage sheds, together with hot-water facilities, and tanks for sterilizing the cans. There all waste materials are collected and turned over to the contractors, who remove them to a point at least 3 miles from the reservation.

In devising this plan for the sale of waste materials, the fact was recognized that some were more salable than others. Consequently, a plan was developed whereby all waste materials, except manure, are sold at a certain price per capita each month. Manure, in the majority of cases, is sold at a price per animal per month. By this plan all waste materials, at all the National Army Cantonments and Embarkation Camps, have been sold, for a total sum of $446 394.57; manure, $198 269.40; or a total for both classes of materials of $644 663.97. This plan not only shows a substantial return to the Government, but will also result in saving $700 000, which would be the cost of erecting incinerators having sufficient capacity to dispose of all waste material if burned. It also shows a saving of about 60 cents per ton for fuel required to burn such waste materials as would accumulate at army cantonments. It is estimated that 40 tons of such wastes accumulate each day at each cantonment. This would cost about $122 275 per year for incineration.

The hardest problem has been to dispose of the manure to advantage. As there are 12 000 animals at each cantonment, manure would necessarily accumulate in large quantities, estimated at not less than 120 tons per day per camp. The cost to the Government of hauling or incinerating this manure would amount to 60 cents per ton. At the date of Lt.-Col. Ellison's report (September 6th, 1917), the manure at eleven cantonments had been sold, in some cases, on the per-animal-per-day basis, and in others on a flat rate per month, resulting in a net return to the Government of $240 900. The total returns to the Government, including money derived from sales, together with savings over incineration, amount to $1 707 838.67. The foregoing statement shows, not only a financial gain to the Government, but also an economic advantage in the recovery of valuable products from such wastes.

At practically all the cantonments, contracts have been made with local contractors for the purchase and removal of the camp wastes, which include bones, garbage, waste paper, bottles, miscellaneous scrap metals, and stable manure. The prices paid by the various contractors (each under a $25 000 bond), range from 3 to 9 cents per man per month, an average of 5 cents. There are a few exceptions, as at Camp Devens, where a lump sum of $2 160 per month for all camp wastes, is paid by the contractor; and at San Antonio, where the bones bring $11.00, garbage $1.90, and waste paper $4.00, per ton.

In the National Guard Camps, the kitchen wastes are burned in incinerators of the field type. Manure in many cases is disposed of by filling low, swampy land near the camps.

Roads, Walks, and Pavements.

Specifications were issued for four standard types of roads, namely, water-bound macadam, bituminous macadam, brick, and cement-concrete, and such paragraphs from each specification were utilized as were applicable to the work to be undertaken.

No single type of road construction was adopted for use in all cantonments and camps. Roads constituting main arteries of traffic have in general been paved with brick, concrete, asphaltic concrete, water-bound macadam, and bituminous macadam, the type of construction depending on a number of factors, such as availability of materials, character of subgrade, type of construction, equipment, and speed of construction. The standard width of pavement adopted was 18 ft., although in some instances pavements 24 ft. wide have been constructed.

The construction of walks was not, in general, authorized. Gravel or crushed stone walks have been constructed in a few instances, particularly in the vicinity of hospitals, and, in some cases, around the more important buildings, such as division and brigade headquarters, camp post offices, telegraph offices, etc.

Nearly all the sidewalks in most of the camps are of wooden strips, or boards, laid on cross-pieces. Cinders, where available, were also used for walks.

Lighting.

General.—Electrical energy for all purposes is purchased from public service electric companies in the form of alternating current. From the main substation, feeders distribute the power through the property at 2 200 volts, 3-phase. At intervals there are pole-type transformers, which reduce the voltage to 110 or 220, with single-phase, 3-wire utilization in the buildings.

Exterior Lighting.—Series systems are used throughout, with 6.6-ampere, 100-c.p. lamps and radial-ray reflectors on goose-neck brackets attached to poles. These lamps are from 250 to 350 ft. apart, according to the requirements. To guard against interruptions covering large areas, the lighting is arranged in groups, each of which is supplied by a pole-type constant-current transformer, which is controlled by a pole-type oil switch, operated from the ground by ropes.

Interior Lighting.—In order to simplify the work, and also the purchase of materials, a standard arrangement of 40-watt lamps is in use, generally. Places in which lamps of other sizes are used are generally garages and other buildings which necessarily require especially good lighting. The intensity of illumination in the barracks and in buildings of this type is approximately 0.2 watt per sq. ft. of floor area which corresponds to about 1 ft. per watt; in mess rooms and kitchens it is somewhat higher, and in sleeping quarters it is somewhat less.

The systems of wiring, generally, are open cleat, or concealed knob and tube. In garages and laundries the conduit system is used. Buildings are provided as required with a service switch, and, where there are a number of circuits, the fuses are all grouped at one point.

Metal cone reflectors are used generally, with wire lamp guards in lavatories, storerooms, or other places where the lamps are subject to breakage.

HEATING.

At National Army Cantonments, with the exception of Camps Devens, Grant, Custer, and Dodge, nearly all buildings are heated by stoves and room heaters. This method is, in general, more successful than was at first anticipated, as it was felt that the heating of barrack buildings of this type with heaters placed in the dormitories was a new departure.

Stoves.—About 45 000 room heaters, or furnaces cased as room heaters, have been purchased, together with about 30 000 cannon stoves.

Steam Plants.—In the regimental heating plants, particularly, every detail which was not absolutely essential to the heating of buildings was eliminated in order to conserve time, labor, and material.

In connection with the heating at cantonments, about 300 horizontal tubular boilers, of 150 h. p., were purchased and erected representing a total of 45 000 h. p. In addition, there were about 150 large and 1 700 small cast-iron boilers, of the sizes ordinarily used in residence heating. For heating at National Army Cantonments, a total of approximately 4 700 000 sq. ft. of cast-iron radiation was purchased.

HOSPITALS.

Surgeon-General Gorgas recommended hospital facilities with 1 000 beds for each cantonment. This was done, with perhaps one or two exceptions, where 500-bed hospital arrangements were provided at the outset.

It is unnecessary to go into further details, except to refer to the cost data, which show that at the 16 cantonments the hospital construction cost $10 159 333, and at the 16 Guard camps it was $7 502 651.

GENERAL UTILITIES AND APPURTENANCES.

Much attention was necessary for many of these detailed arrangements, including refrigerating plants, laundries to serve an entire cantonment, bakeries, storehouses, railroad sidings, and the like. Details are unnecessary here.

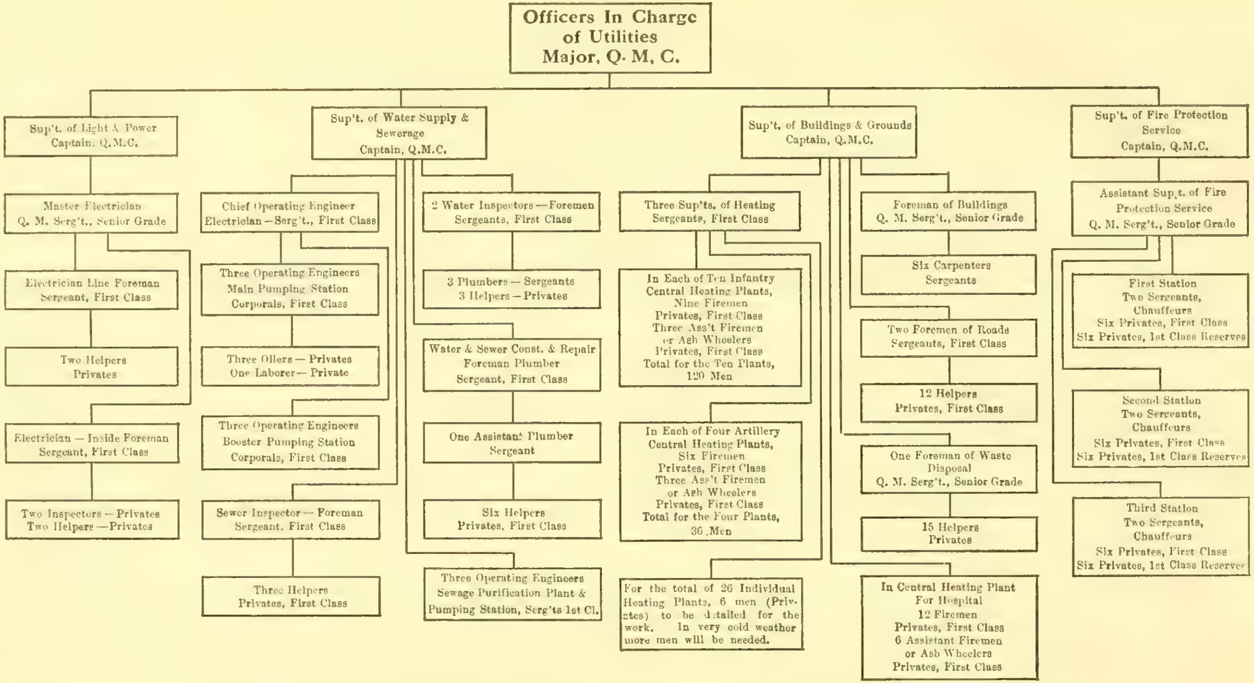
A word also may be said as to the liberality with which arrangements were made to entertain the troops, such as "hostess" houses, Y. M. C. A., and Knights of Columbus, buildings, theatres, and similar amusement facilities.

SWAMP DRAINAGE AND MOSQUITO ELIMINATION.

During the construction period some attention was given to these items. At Camp Upton, Yaphank, Long Island, the mosquito situation was serious in the early days of construction, which happened to follow quite an unusual period of rainy weather.

In instances known to the writer the Camp Surgeons detailed to aid the Constructing Quartermasters were very proficient in handling this phase of the work.

What the programme is to be in 1918 as to mosquito elimination is not definitely known, although it is stated that it has received careful consideration, and recommendations have been made for an effective campaign.


Officers In Charge of Utilities Major, Q. M. C.
Sup't. of Light & Power Captain, Q.M.C.
Master Electrician Q. M. Serg't., Senior Grade
Electrician Line Foreman Sergeant, First Class
Two Helpers Privates
Electrician — Inside Foreman Sergeant, First Class
Two Inspectors — Privates Two Helpers — Privates
Sup't. of Water Supply & Sewerage Captain, Q.M.C.
Chief Operating Engineer Electrician — Serg't., First Class
Three Operating Engineers Main Pumping Station Corporals, First Class
Three Oilers — Privates One Laborer — Private
Three Operating Engineers Booster Pumping Station Corporals, First Class
Sewer Inspector — Foreman Sergeant, First Class
Three Helpers Privates, First Class
2 Water Inspectors — Foremen Sergeants, First Class
3 Plumbers — Sergeants 3 Helpers — Privates
Water & Sewer Const. & Repair Foreman Plumber Sergeant, First Class
One Assistant Plumber Sergeant
Six Helpers Privates, First Class
Three Operating Engineers Sewage Purification Plant & Pumping Station, Serg'ts 1st Cl.
Sup't. of Buildings & Grounds Captain, Q.M.C.
Three Sup'ts. of Heating Sergeants, First Class
In Each of Ten Infantry Central Heating Plants, Nine Firemen Privates, First Class Three Ass't Firemen or Ash Wheelers Privates, First Class Total for the Ten Plants, 120 Men
In Each of Four Artillery Central Heating Plants, Six Firemen Privates, First Class Three Ass't Firemen or Ash Wheelers Privates, First Class Total for the Four Plants, 36 Men
For the total of 26 Individual Heating Plants, 6 men (Privates) to be detailed for the work. In very cold weather more men will be needed.
Foreman of Buildings Q. M. Serg't., Senior Grade
Six Carpenters Sergeants
Two Foremen of Roads Sergeants, First Class
12 Helpers Privates, First Class
One Foreman of Waste Disposal Q. M. Serg't., Senior Grade
15 Helpers Privates
In Central Heating Plant For Hospital 12 Firemen Privates, First Class 6 Assistant Firemen or Ash Wheelers Privates, First Class
Sup't. of Fire Protection Service Captain, Q.M.C.
Assistant Sup't. of Fire Protection Service Q. M. Serg't., Senior Grade
First Station Two Sergeants, Chauffeurs Six Privates, First Class Six Privates, 1st Class Reserves
Second Station Two Sergeants, Chauffeurs Six Privates, First Class Six Privates, 1st Class Reserves
Third Station Two Sergeants, Chauffeurs Six Privates, First Class Six Privates, 1st Class Reserves

ORGANIZATION CHART FOR THE OPERATION OF UTILITIES AT NATIONAL ARMY CANTONMENTS.

This chart was drawn to apply to Camp Devens, and was modified to suit other cantonments. It does not include any of the personnel for laundry, refrigerating plant, or telephone service.

FIG. 3.

Additional screens have also been recommended, and it is to be hoped that they will be forthcoming at all camps where needed and thus lessen the possibilities of transmission of disease by flies. Early provision was made at some of the camps for screening hospitals, kitchens, and mess halls.

Utility Management.

One of the recommendations of the Committee on Engineering and Sanitation was that careful records should be made of all structures built, particularly those underground, such as water pipes, sewers, and the like.

Another recommendation was that due care should be taken in obtaining efficient organizations for operating the several utilities.

A Major in the Quartermaster Corps has been put in charge of utilities at practically each camp, and he is scheduled to be equipped with a staff such as is shown by the organization chart, Fig. 3. This chart covers all utilities except the personnel for laundry, refrigerating plant and telephone service.

The officers in charge of utilities at the several National Army cantonments as of December, 1917, were as follows:

Maj. Paul Doty, Camp Grant, Rockford, Ill.,
Capt. E. W. Briggs, Camp Devens, Ayer, Mass.,
Maj. E. B. Whitman, M. Am. Soc. C. E., Camp Meade, Admiral, Md.,
Maj. C. A. Watrous, Camp Dodge, Des Moines, Iowa,
Capt. H. L. Hall, Camp Gordon, Atlanta, Ga.,
Maj. Walter E. Spear, M. Am. Soc. C. E., Camp Upton, Yaphank, N. Y.,
Maj. Murray Warner, Camp Dix, Wrightstown, N. J.,
Maj. William McK. Scott, Camp Lee, Petersburg, Va.,
Maj. Eugene Betts, Camp Jackson, Columbia, S. C.
Maj. R. L. McDonald, Camp Sherman, Chillicothe, Ohio,
Capt. A. E. Barbour, Camp Zachary Taylor, Louisville, Ky.,
Maj. T. A. Leisen, M. Am. Soc. C. E., Camp Custer, Battle Creek, Mich.,
Maj. G. F. Huestle, Camp Pike, Little Rock, Ark.,
Maj. W. L. Benham, M. Am. Soc. C. E., Camp Funston, Fort Riley, Kans.,

Maj. Frank H. Todd, M. Am. Soc. C. E., Camp Travis, San Antonio, Tex.,

Maj. John C. Hays, M. Am. Soc. C. E., Camp Lewis, American Lake, Wash.

At Camp Meade, which covers an area of about 2 by 3 miles, and where there are about 1 800 structures, accommodating 40 000 men and 12 000 animals, the Utility Division comprises 343 officers and enlisted men and 35 civilian employees.

NEED FOR CO-ORDINATION.

Bearing in mind the urgency with which all utilities are operated in the interests of sanitation, and the health of the troops, there have been some misgivings as to the lack of co-ordination in the organizations having charge of the supervision or some jurisdiction over matters relating to sanitation.

Army regulations provide that camp sanitation is in the hands of the Camp Surgeon.

The officers in charge of utilities serve under the Camp Quartermaster, who, naturally enough, shares the viewpoint of the Commanding General of the cantonment in the main problem of getting the troops trained and taking them abroad. He is eager to avoid sickness, but it is not to be expected that he or his staff officers have time for details of a sanitary nature, particularly preventive steps to guard against troops becoming indisposed so that they appear on the hospital list or are rated temporarily as ineffectives.

Not only has the Camp Quartermaster, Camp Surgeon, and the Utility Superintendent, authority in these matters, but there is also to be reckoned with the members of the Sanitary Corps of the Surgeon General's Office, and the representatives of the Construction and Repair Division of the Quartermaster General's Office, from which originally sprang the Cantonment Division itself.

During the past winter, at least the Cantonment Division, now the Construction Division, had little or no authority, either with regard to the operation or betterments of utilities related to sanitation at the camps. It is believed that this is important, and that steps looking to correction should not be delayed. In this way alone can the intent of the designers be put clearly before those who are responsible for operations, and, as already set forth, water supply and sewage disposal matters are essentially ones which call for efficient operation. The best of plants will fall down sooner or later if not operated efficiently and in appreciation of the intent of the designers.

It is understood that very recently a Maintenance and Repair Branch, in Charge of Utilities and Buildings, has been taken from the Quartermaster General's Office and put under the Construction Division. It is sincerely to be hoped that suitable personnel can quickly be secured to make this important branch function efficiently, especially in its relation to the protection of the health of the Army.

ACCREDITING AND EXPANSION OF CANTONMENT DIVISION INTO PRESENT CONSTRUCTION DIVISION.

It was a source of great satisfaction to all civil engineers and others associated with the cantonment work in its earlier days to find that, after Congressional investigations, the Cantonment Division as a unit was to be held together and put in responsible charge of additional construction (more than $600 000 000) aggregating in cost several times that of the existing cantonment work. These men have performed most creditably a large piece of work, in the face of great difficulties, in an almost incredibly short space of time; and they know how to do Government work and how to work in co-ordination with each other and with contractors' organizations.

No greater compliment could be paid to Gen. Littell and his successor, Col. R. C. Marshall, Jr., and the many able engineers in the Construction Division than to be entrusted with such an enormous increase in their responsibilities.

In view of the many millions of dollars worth of work placed in charge of this new Division of the Army, and the wide range of such work involved, it is worth while to record the style of organization and its various sub-divisions as it existed at the end of March, 1918. Even the sections of the different branches are of value to the student of organizations for carrying on large work. The personnel is likewise of some interest, although it is given with the realization that perhaps it may unintentionally, through omission, do scant courtesy to the representatives of the Construction Division on the field work at various places throughout the country.

ORGANIZATION OF THE CONSTRUCTION DIVISION OF THE ARMY.

Construction Division of the Army.—This division is in charge of Col. R. C. Marshall, Jr., Q. M. C. N. A. It has control over, and is charged with all matters in connection with the construction work of the army in the United States, the Hawaiian Islands, Porto Rico, and the Canal Zone, including the surveying and other necessary preliminary work on the sites selected, preparation of plans, procuring, inspecting, and expediting of materials, actual construction work, putting in place equipment of all sorts, construction of roads, wharves, sewer systems, and water systems, attention to the matter of rentals and leases, the maintenance and repair of all construction projects, and the operation of public utilities on such projects; it also has charge of the allotment of funds to cover the expenditures incident to these activities; it co-operates with other departments and bureaus of the War Department for which, or at whose request, it has been authorized to proceed with construction work; and generally has control over all matters connected with, or arising out of, its general operations and activities.

This Division includes the following branches:

Engineering Branch,
Contracts Branch,
Administrative Branch,
Constructing Branch,
Maintenance and Repair Branch,
Accounting Branch,
Materials Branch.

Engineering Branch.—Col. F. M. Gunby, Q. M. C. N. A., in charge; Assistant in charge, Lt.-Col. L. Bush, Q. M. C. N. A.; Executive Officer, Lt.-Col. C. C. Wright, Q. M. C. N. A., and Maj. G. R. Solomon, M. Am. Soc. C. E., E. R. C., assisting. It has supervision over the preparation of all plans and specifications for cantonment and other emergency construction, including buildings, water and sewer systems, roads, walks, wharves, drainage, heating, lighting, power, plumbing, railroads, docks, and other elements entering into this construction; has charge of the preparation of estimates of cost for the same, and the preparation of bills of material entering into all the construction outlined above.

(a) *Architectural Work Section:* Lt.-Col. F. B. Wheaton, Q. M. C. N. A., in charge.

(b) *Estimates Section:* Maj. H. S. French, Q. M. C. N. A., in charge.

(c) *Camp Planning Section:* Maj. George Gibbs, Jr., Q. M. C. N. A., in charge.

(d) *Water Supply Section:* Lt.-Col. D. H. Maury, M. Am. Soc. C. E., Q. M. C. N. A., in charge.

(e) *Fire Protection Section:* Mr. H. E. Newell in charge.

(f) *Electric Equipment Section:* Maj. N. J. Neall, Q. M. C. N. A., in charge.

(g) *Illumination Section:* Mr. A. L. Pearson in charge.

(h) *Heating and Plumbing Section:* Maj. L. H. Tripp, Q. M. C. N. A., in charge.

(i) *Expediting Section:* Maj. H. J. Burt, M. Am. Soc. C. E., Q. M. C. N. A., in charge.

(j) *Roads and Sanitation:* Maj. L. S. Doten, M. Am. Soc. C. E., Q. M. C. N. A., in charge.

(k) *Schedules Section:* Mr. G. G. Will in charge.

(l) *Refrigeration Section:* Mr. L. R. Phillips in charge.

(m) *Special Studies Section:* Mr. H. M. North in charge.

(n) *Mechanical Engineering Section:* Mr. J. B. Blake in charge.

(o) *C. E. and Track Work Section:* Capt. A. F. Dershimer, Q. M. C. N. A., in charge.

Administrative Branch.—Col. J. H. Alexander, Q. M. C. N. A., in charge. Handles all matters pertaining to supervising, developing, and perfecting administration and operation in the Construction Division and in co-ordinating the activities of the various branches and sections thereof; has supervision over clerical routine, records, files, mail and messenger service; handles routine and miscellaneous correspondence; settles matters of office policy; attends to the issuing of travel orders for officers and civilians, assignments to and relief from duty, keeps records of the officers assigned to duty under the direction of the Officer in Charge of Construction Division; handles all matters connected with the employment, pay, and separation from service of civilian employees of the office; has supervision and control over stenographic and mimeographic service; attends to the purchase and distribution of office supplies and equipments, and conducts a general information bureau. Also has supervision over co-ordination of labor rates and conditions at all construction points carried on under the Construction Division, and passes upon agreements in connection therewith. Deals with all union officials and with the Cantonment Adjustment Commission of the War Department; supervises compilation and records of all labor rates, conditions, and agreements; secures and prepares all required statistics covering cost and other special matters required in connection with reports to other branches of the War Department. Its sections are:

(a) *Personnel Section:* Maj. G. H. Thompson, Q. M. C. N. A., in charge.

(b) *Mail and Record and Miscellaneous Section:* Capt., W. G. Maupin, Q. M. R. C., in charge.

(c) *Information Section:* Capt. A. H. Erck, U. S. Inf., in charge.

(d) *Labor and Statistic Section:* Maj. H. F. Mayor, Q. M. C. N. A., in charge.

(e) *Stenographic and Property Section:* Mr. A. B. Moreland, Chief Clerk, in charge.

Constructing Branch.—Col. M. J. Whitson, Q. M. C. N. A., in charge, and Col. Peter Junkersfeld, Q. M. C. N. A., assisting. Lt.-Col. W. R. Roberts, Q. M. C. N. A., Executive Officer. This branch has charge of construction of all sorts in connection both with permanent and temporary work; carrying out the plans prepared by the Engineering Branch; it appoints supervising constructing quartermasters and constructing quartermasters, co-ordinating the supervision, expedition, and completion of construction; it issues requisitions for the necessary principal materials, and designates what part of the same shall be mobilized or purchased through this office and what part shall be purchased from local stock. It expedites and follows up the work under way, and maintains progress charts and statistical data pertaining to the same; it maintains close relation with constructing quartermasters in the field, regarding all questions pertaining to work in progress, and supervises all relations with the contractors carrying out construction projects. It conducts the necessary correspondence pertaining to all work under its supervision and keeps in close touch with such work until its completion, and its turn-over. This branch is divided into the following sections:

(a) *Section A:* Lt.-Col. O. P. Chamberlain, Q. M. C. N. A., in charge. Has control over construction work of all kinds in connection with National Army Cantonments, National Guard Camps, Miscellaneous Cantonments, Hospital and Quartermaster Repair Shops.

(b) *Section B:* Lt.-Col. R. M. White, Q. M. C. N. A., in charge. Has supervision over construction of storage and traffic facilities, terminals, lighters, and warehouses.

(c) *Section C:* Lt.-Col. G. F. D. Trask, Q. M. C. N. A., in charge, assisted by Maj. B. B. Lathbury, M. Am. Soc. C. E., Ord. R. C. Has supervision over construction of Ordnance Depots, Ordnance Manufacturing and Proving Plants.

(d) *Section D:* Lt.-Col. G. B. Walbridge, Q. M. C. N. A., in charge. Has supervision of construction of Signal Corps Plants and Depots; Housing and miscellaneous projects.

(e) *Section E:* Maj. H. W. Lockett, Q. M. C. N. A., in charge and Maj. J. B. Coleman, Q. M. C. N. A., assisting. Supervises construction at Coast Artillery and interior army posts.

(f) *Protection and Investigation Section:* Lt.-Col. Philander Betts, Q. M. C. N. A., in charge.

(g) *Government Equipment and Material Section:* Lt.-Col. E. C. Stockdale, Q. M. C. N. A., in charge.

Materials Branch.—Col. J. N. Willcutt, Q. M. C. N. A., in charge; Lt.-Col. J. M. Pease, Q. M. C. N. A., Assistant in charge. Has supervision over the procurement, inspection, expediting, and delivery of all materials mobilized through the Construction Division, for use in construction work which it has in hand; co-operates with the various committees and other organizations which have been formed with a view to stabilizing prices and keeping in touch with the entire market throughout the country for the procurement of materials and articles which are required. Confers with the officers of the Director General of Railroads and transportation officials and organizations with a view to securing rolling equipment for the rapid movement of material and expediting the movement of cars. It is divided into sections as follows:

(a) *Procurement Section:* Maj. O. F. Noss, Q. M. C. N. A., in charge. Has control of the procurement and mobilizing of building material of all natures, plumbing, lighting, power, heating and cooking fixtures and equipment, sand, gravel, cement, steel, and all articles of material necessary for use in construction work or incident thereto. The Procurement Section is divided into departments as follows:

(1) *Building Materials Department:* Capt. A. S. Dorsey, Q. M. R. C., in charge.
(2) *Steel Department:* Capt. H. C. Dissell, Q. M. R. C., in charge.
(3) *Steam Heating Department:* Capt. W. H. Riblet, Q. M. R. C., in charge.
(4) *Electrical Equipment Department:* Capt. J. E. Erickson, Q. M. C. N. A., in charge.
(5) *Plumbing Supplies Department:* Capt. J. C. McCubbin, Q. M. C. N. A., in charge.
(6) *Water Supply Department:* Capt. M. O. Pinkham, Q. M. C. N. A., in charge.
(7) *Mechanical Equipment Department:* Capt. A. C. Nell, Q. M. C. N. A., in charge.
(8) *Store and Special Equipment Department:* Capt. E. W. Case, Q. M. C. N. A., in charge.
(9) *Fire Protection Department:* Capt. G. Litchfield, Q. M. C. N. A., in charge.
(10) *Hardware Department:* Mr. A. P. Chandler in charge.
(11) *Paints and Refrigeration Department:* Mr. J. H. Prentiss in charge.

(b) *Delivery Section:* Lt.-Col. H. S. Durant, Q. M. C. N. A., in charge; Assistants, Capt. J. M. Ritchie, Assoc. Am. Soc. C. E., Q. M. R. C., Capt. A. B. Nash, Q. M. C. N. A. Follows up production, manufacture, inspection, and transportation of all materials purchased and procured through the Procurement Section. This section is divided into the following departments:

(1) *Transportation Department:* Mr. C. E. Denney in charge. assisted by Capt. F. M. Palmer, Q. M. R. C.
(2) *Inspection Department:* Capt. F. W. Hatten, Q. M. C. N. A in charge.
(3) *Expediting Department:* Mr. S. G. Stouch in charge.

Accounting Branch.—Lt.-Col. Charles Neville, Q. M. C. N. A., in charge, assisted by Mr. William Whitfield. Is concerned with all accounting and financial matters pertaining to the Construction Division; interprets such parts of contracts as relate to accounts; acts in an advisory capacity for Government accounting forces on the various jobs in course of construction; sends out traveling accounts to the jobs; maintains records relating to appropriations, authorizations, allotments, and transfers of funds in connection therewith; allots to operating branches funds which have been allotted for the purpose of the Construction Division; assembles cost data and financial statistics relative to all jobs. This branch has the following sections:

(a) *Traveling Accountants Section:* Mr. William Whitfield, C. P. A., in charge.
(b) *Cost Accounting Section:* Capt. C. A. Duff, Q. M. R. C., in charge.
(c) *Funds Section:* 1st Lieut. R. E. Dudley, Q. M. C. N. A., in charge.
(d) *Field Accounting Section:* Mr. C. D. Block in charge.
(e) *Prior Construction Section:* Mr. E. F. Cassel in charge.
(f) *Personnel Section:* Mr. C. D. Block in charge.
(g) *Miscellaneous Section:* Mr. N. W. Phillips in charge.

Maintenance and Repair Branch.—Lt.-Col. C. D. Hartman, Q. M. C. N. A., in charge, Maj. Paul Doty, Q. M. C. N. A., assisting. Is concerned with all work of maintenance and repair at permanent and temporary army posts and camps, and at other places where Government construction work has been done, carrying out plans prepared by the Engineering Branch, and by itself, connected with matters of maintenance and repair. It corresponds with local officers in charge of maintenance work in regard to plans and all matters incident to the same and to the work of the branch, and allots funds in connection with its activities. It is divided into sections as follows:

Land and Lease Section: ? Officer in charge.
Building Repair Section: Maj. D. S. Clinton, Assoc. M. Am. Soc. C. E., Officer in charge.
General Maintenance and Repair Section: Capt. G. A. Knight, Officer in charge.
Utilities, Operation and Maintenance Section: Capt. J. C. Donald, Officer in charge.
Technical Service Section: ? Officer in charge.
Procurement Section: Capt. E. M. Aten, Officer in charge.
Statistical Section: Capt. E. E. Whiting, Officer in charge.

Contracts Branch.—Col. Evan Shelby, Q. M. C. N. A., in charge. Has general supervision over all documents in the nature of contracts and leases pertaining to or in connection with the work of the Construction Division; determines what matters shall be submitted to the Judge Advocate General for opinion; attends to all matters relating to surety bonds, fire insurance, workmen's compensation, and employer's liability insurance, and all questions arising in connection therewith. This branch is divided into sections as follows:

(a) *Contract Section:* Col. Evan Shelby, Q. M. C. N. A., in charge.
(b) *Insurance Section:* Mr. Lee J. Wolfe in charge.

ACKNOWLEDGMENTS.

The writer desires to express his deep appreciation for the courtesies extended to him by Col. Marshall for permission to publish, at the request of the meeting of the American Society of Civil Engineers on April 3d, 1918, the data appearing in this paper. Part of the data came from the notes of the writer, and part was furnished through the kindness of Col. Marshall. The lantern slides came from these two sources, supplemented by some from Morris Knowles, M. Am. Soc. C. E., showing details of construction at Camps Meade and McClellan.

Lessons from Experiences with Emergency Construction Work.

As the writer has reflected on the experiences with emergency contruction work as developed with the cantonments, certain features have grown more and more clearly crystallized in his mind. It is believed that they are capable of discussion and expansion, with the end in view of making current experiences with emergency work available for the better guidance of the Profession in other emergencies in the future. The main thoughts are as follows:

1.—In emergency construction work, especially under war conditions, economy of time is fundamentally necessary.

2.—Economy in funds is well worth considering, but it should not be carried to such an extent that ensuing delays bring about losses in life and money, through needless prolongation of the war, and so that consequential losses of blood and of funds entirely outweigh the benefits of initial savings.

At a time when there is raging the greatest battle that the world has ever known, no prudent man can be disposed to quibble over reasonable expenditures which produce speed in completing the works demanded.

3.—Adequate engineering direction is vital to speedy and satisfactory construction of sizeable work of all kinds, but its importance in emergency work is increased manyfold.

4.—The first essential is to find out definitely what is wanted, where the work is to be built, and what serviceable materials can be most quickly assembled. Then the programme should be stated in such clear and simple form, with concise specifications and typical plans, that all trained men will thoroughly understand the primary object sought.

If an engineering organization is strong enough to take this step wisely and quickly, it is likely to know how to get together an organization which will execute the work satisfactorily and promptly if it is not confronted with too many changes in plans over which it has no control.

If engineers are not able to get started right, neither they nor any one else are likely to avoid wastage of time and of money; and usually both are wasted.

5.—The second essential is that standard designs of the primary works should be made at a central office possessing knowledge of military exigencies and requirements, availability of materials, priority arrangements as to transportation, and needs as to where limited quantities of construction material can be used to best advantage.

The fitting of typical plans in many of their details must be done on the ground by a local engineering organization which must secure knowledge of local matters not known at the central office, such, for instance, as topography, transportation facilities, soil conditions, availability of water supply, drainage, etc.

It is hardly necessary to say that it is folly to hold up active construction by waiting until the resident engineering organization on the ground can furnish details to the central office hundreds or thousands of miles distant. Headquarters department must not try to do both its own work and the details which can properly be done only by those on the site of the construction work. Conversely, the local organization, no matter how efficient it may be in civil pursuits in times of peace, cannot ordinarily succeed on emergency war work, of some types at least, because it is insufficiently posted as to military exigencies, and has insufficient appreciation of what is wanted and what is not wanted, and particularly is it at sea in the matter of materials, transportation, etc.

6.—Elasticity of programme sufficient to allow a proper adjustment of typical plans to local conditions involves the vitally important step of giving the local representative on the ground adequate authority. Responsibility without authority is always a misfortune on engineering work, but on war work it is positively disastrous. To give a man in local charge proper authority, it is necessary on Government work to cut all red tape that is possible. This explains much of the success of the Cantonment Division.

Delegation of authority may not result happily; but, if things go wrong, or are slow, the fault is ordinarily in the personnel and not in the basic principle of organization just stated.

Nothing is so disastrous to emergency work under war conditions as the high official who will neither do things himself nor delegate adequate authority to somebody else to do things.

"Passing the buck" has become a commonplace saying in Washington during the past year. At the outset some such performances were inevitable; but the expression is a plainful reminder of what lack of preparation means on emergency war work.

7.—The contract under which emergency construction work is built must be on such a basis that delays at the outset will be absolutely minimized, radical changes can be made if need be during the progress of the work, and adjustments under proper supervision made to the fluctuations of an unstable market for labor and materials. These conditions are not met by any lump-sum or unit price basis for bidding competitively, but they are met by the emergency contract form of the Cantonment Division providing suitable Government supervision for payment of cost plus a sliding percentage scale with a maximum upset fee to the contractor.

This form of contract is thoroughly fair to the Government if it is efficient and practical in its supervision over the contractor, and it is fair to the contractor if the Auditing Department does not hold up payments so as to make the contractor give up a large share of his earnings as interest charges on deferred payments.

The unqualified endorsement of the current form of contract, in use on emergency construction work of the War Department, by a Committee of distinguished engineers, labor representatives, and business men, is pre-eminently sound.

8.—Efficient co-operation and team work are essential to the successful execution of all engineering work. Petty jealousies and the friction arising through the failure of men with a low coefficient of adaptability to realize the importance of team work, are far more disastrous to emergency war work than to engineering work in times of peace. Civilian engineers who do not fully appreciate this, or will not quickly learn it, will serve their country best by staying at home.

9.—Proper operation and proper use of emergency construction work involve the recognition of the basis of design and construction. Camp water supplies, for instance, will not prove satisfactory if radical departures in their use are made from conditions assumed by the designers. Utilities must be operated on a co-ordinated basis as strictly enforced as any other line of performance of the military establishment.

If available facilities do not fairly meet modified conditions, then changes in the structures should be made on a basis conformable to the consensus of opinion of those in authority, from all interested viewpoints.

10.—Conservation of human life, using the expression in its broadest sense, is always a consideration of prime importance. Even when the battle of Picardy is raging, it is well to remember that more soldiers die from disease than from wounds. Camp sanitation must be commensurate with the best and safest practice now known to the art, in order to satisfy the American public that its sons are given a square deal.

11.—It is proper for civilians to point out clearly and repeatedly to representatives of the Government what, in their opinion, are pressing shortcomings in relation to construction work; but it is not proper for civilians to exploit their conclusions as to what, when, and where, steps as to remedial measures are to be taken. That function is vested in the commanding officers of the military establishment, and perhaps in the President himself as the Commander-in-Chief.

Civilians who attempt to draw unqualified conclusions from partial evidence are bound to go wrong, and promptly to wear out their welcome as helpful friendly advisers. Unconsciously, they join the class of obstructing critics.

12.—When civilian engineers have completed an assigned task on emergency work it is sound advice for them to put their records in shape, go home, and attend to civilian affairs. In this way they avoid becoming obstructionists in the path of those engineers detailed either as operating men or as construction men on extension work connected with any given enterprise. Furthermore, if they are at home attending to their ordinary duties the Government, if it desires, can readily find them for another assignment on emergency work.

13.—It is needless to speak further of the lessons taught by the Cantonment Division respecting emergency construction work. If attempted it would simply mean an elaboration of deductions from the foregoing essentials which can all be summed up in the expression "adequate engineering direction".

In view of the accomplishments which are fresh in the minds of all, it is well to remember that the work of the past year is not without its defects, and that it could and would be done better if it were to be done again, in the light of present experiences. What the various betterments should be cannot be told offhand, but the data should be collected, studied, and summarized, so as to be available in future emergencies. It is well to remember that future wars, emergencies from floods, earthquakes, droughts, and riots, may come to any peaceful nation without warning. The more adequately prepared the members of our profession become for handling emergency work the better citizens and better engineers will they be.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

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DETENTION RESERVOIRS WITH SPILLWAY OUTLETS AS AN AGENCY IN FLOOD CONTROL

Discussion.*

BY H. A. PETTERSON, ASSOC. M. AM. SOC. C. E.

Mr. Petterson.

H. A. PETTERSON,† ASSOC. M. AM. SOC. C. E. (by letter).‡—This paper, written by so eminent a man as the late Gen. Chittenden, should help to remove some of the bias which, to the writer's mind, exists against the use of reservoirs in flood control projects.

As one example of this biased mental attitude, from which even the author was not free twenty years ago, the following quotation§ is offered:

> "Floods are only *occasional* calamities at worst. Probably on the majority of streams destructive floods do not occur, on the average, oftener than once in five years. Every reservoir built for the purpose of flood protection alone would mean the dedication of so much land to a condition of permanent overflow in order that three or four times as much might be redeemed from occasional overflow. One acre permanently inundated to rescue three or four acres from inundation of a few weeks once in three or four years, and this at a great cost, could not be considered a wise proceeding, no matter how practicable it might be from engineering considerations alone."

On the supposition stated, that destructive floods do not occur oftener than once in 5 years, on an average, why is it reasonable to assume that the reservoir basin will be in a condition of "permanent" overflow? As a matter of fact, most of the area of the basin would be in a dry condition oftener than lands between levees, or lands occupied by a by-pass, or auxiliary channel. For, in the latter two cases, all

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* Discussion of the paper by the late H. M. Chittenden, M. Am. Soc. C. E., continued from February, 1918, *Proceedings*.

† Tientsin, China.

‡ Received by the Secretary, April 16th, 1918.

§ From "Reservoir Sites in Wyoming and Colorado", p. 46.

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the land would be submerged by every flood, but only a part of the total reservoir would be submerged by the average flood. It should be borne in mind that the reservoir capacity is designed for a flood of exceptional magnitude, which will not occur oftener, on an average, than once in 50 years, or longer, so that the basin will be completely filled only at these rare intervals of time. If the land is suitable for agricultural purposes, the greater part of it could be used for such purposes more frequently than (1) lowlands overflowed at every high water, (2) lands between the river and levee, (3) lands occupied by a by-pass or auxiliary channel.

To illustrate graphically the great probable yearly variation in water content of a flood prevention reservoir, Fig. 4 is presented. It is based on data contained in United States Water Supply Paper No. 334. Table 2 is based on the same data plotted on "probability paper" after the method proposed by Allen Hazen, M. Am. Soc. C. E.* This table shows that the reservoir would be full to capacity on an average of only once in 100 years; it would be filled to four-tenths of its capacity ten times in 100 years, or once in 10 years, on an average; and for nearly 50 years out of every 100 it would be empty throughout the whole year. It should be borne in mind that, even during flood years, the basin would be completely empty during part of the year.

TABLE 2.—YEARLY VARIATION IN STORAGE REQUIREMENT, FROM DATA OF FIG. 4. RESERVOIR FOR FLOOD PREVENTION.

Reservoir capacity as percentage of $V_m = p\,V_m$.	Percentage of years that $p\,V_m$ will be equalled or exceeded.	Percentage of years when capacity less than $p\,V_m$ will suffice.
100 V_m	1	99
58.5 V_m	5	95
40.2 V_m	10	90
21.8 V_m	20	80
11.5 V_m	30	70
8.0 V_m	40	60
2.8 V_m	50	50
0 V_m	55	45

V_m = maximum capacity for which reservoir is designed.
p = a percentage.
Values of p are tabulated in the first column.

Another instance of mental bias toward reservoirs is exhibited, to the writer's mind, in the statement that the same reservoir cannot be used for both flood prevention and storage for use, as the two pur-

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* "Storage to be Provided in Impounded Reservoirs for Municipal Water Supply", *Transactions*, Am. Soc. C. E., Vol. LXXVII (1914), p. 1539.

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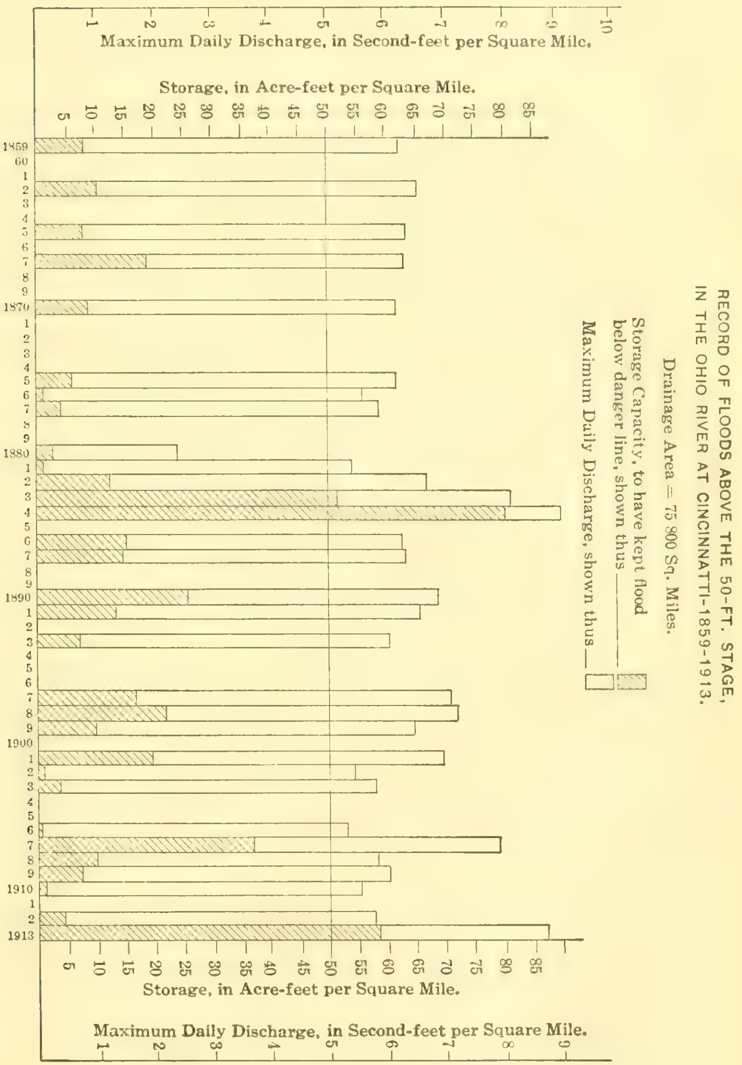

FIG. 4.

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poses are antagonistic. The author has cited a long list of statements bearing on this subject in that part of his paper headed "Conflict and Compromise". He shows that it is possible, of course, to operate a reservoir for these dual purposes if the basin has sufficient capacity; or, in general, if it has a volume, $V_c = F_m + P_m$, where F_m is the capacity required for flood prevention only and P_m is the storage for use.

The writer proposes to show that, in many and perhaps the majority of cases, a capacity, $V_c < F_m + P_m$, may be utilized successfully for the dual purposes mentioned. In general, V_c will be equal to $F_m + bP_m$, where b is a factor the value of which must be determined for each water-shed, and may be anything from 0 to 1.

Flood control by reservoirs involves regulation of the run-off during high stages, so that the controlled run-off, or reservoir outflow, shall not exceed a predetermined rate. The maximum possible value of the outflow is equal to the safe carrying capacity of the channel.

This function of a reservoir may appropriately be called "High-Water Regulation."

"Storage for Use" implies that the unregulated run-off, during certain periods of low water, is less than the desired rate of draft, but, at some stages, the run-off is in excess of the draft. The water impounded in the reservoir must be stored during the season of relatively high flow, but the function of the reservoir is to augment the deficient run-off of the stream during seasons of low flow, and may appropriately be termed "Low-Water Regulation."

The expression "Low-Water Regulation" will be used herein in the same sense as "Storage for Use."

Having explained the sense in which the expressions, "High-Water Regulation" and "Low-Water Regulation" are used, the writer will now attempt to prove that a reservoir can be operated successfully when fulfilling the seemingly antagonistic functions of preventing floods and storing water for use, and that the capacity of this composite reservoir will be less than the sum of the volumes required for flood prevention and storage for use, considered separately; or, in symbols, $V_c < F_m + P_m$.

THE UTILIZATION OF STORAGE RESERVOIRS FOR BOTH HIGH-WATER AND LOW-WATER REGULATION.

To simplify the discussion, it will be taken up under four heads, namely:

A.—Reservoir Capacity for Low-Water Regulation Only.

B.—Reservoir Capacity for High-Water Regulation Only.

C.—Reservoir Capacity for the Combined Function of Both High-Water and Low-Water Regulation.

D.—The Operation of a Reservoir Having This Dual Function.

A.—Reservoir Capacity for Low-Water Regulation Only.

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The following symbols will be used:

P = Volume of storage required, general value. Subscripts will be used to denote particular values.
Q = Intensity of run-off, variable.
Q' = Mean run-off.
D = Rate of draft, variable.
D' = Uniform draft.

The required storage, P, will depend on: (1) the run-off, Q, its distribution throughout the months of any one year, and its variation from year to year; (2) the intensity and seasonal variation of the draft, D.

Storage volumes may be determined from hydrographs, as on Fig. *b* of Plate II, or from mass curves, as on Fig. *a* of Plate II. As the methods of doing this are well known to all hydraulic engineers, they call for no explanation.

It may be worth while to state that, when the draft is uniform, $= D'$, it is shown as a straight line on both hydrograph and mass curve; when the draft is variable, $= D$, it is either a curve or irregular line on both hydrograph and mass curve. The dotted line, designated as "Irrigation Duty" on Fig. *b* of Plate II, is an example of variable draft. Its equivalent on the mass curve is the curved line, "Vector of Irrigation Duty". Storage requirements for a variable draft may be found almost as readily as for a uniform draft. It is simpler to explain certain propositions when the draft is uniform, and, for that reason, a uniform draft, D', will be assumed.

The draft tentatively selected at the beginning of this study was $D' = 0.5\ Q'$. It was desired to adopt a value, D', such that only monthly regulation would be required; that is, no water would have to be carried over from one water year to another. As shown later, a slight year-to-year storage is necessary with $D' = 0.5\ Q'$, but no yearly storage is required when $S' = 0.47\ Q'$.

The maximum storage requirements of each year were first determined from a mass curve. These are shown on Fig. *a* of Plate II as P_3, P_4, P_5, etc.

Their volumes, in thousands of acre-feet, are assembled in Table 3 in order of magnitude.

How are we to know that the largest of these values will suffice for the reservoir? Perhaps if there had been 10 or 20 additional years of records, a capacity considerably greater might have been found necessary. The paper by Mr. Allen Hazen, entitled "Storage to be Provided in Impounding Reservoirs for Municipal Water Supply,"* furnishes the

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* *Transactions*, Am. Soc. C. E., Vol. LXXVII (1914), p. 1539.

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TABLE 3.—LOW-WATER REGULATION STORAGE, IN ORDER OF MAGNITUDE. $D' = 0.5\ Q'$

Year.	P, in thousands of acre-feet
1906	300
1909	300
1912	450
1908	780
1907	900
1911	1 050
1904	1 200
1910	1 350
1915	1 600
1903	2 900
Σ	10 830
Mean.	1 083

TABLE 4.—YEARLY RUN-OFF, IN THOUSANDS OF ACRE-FEET. (Water Supply Paper No. 300, pp. 449-451.)

Year.	Run-off.	Variation from the mean = V.
1902	7 956	— 8 644
1903	11 364	— 5 236
1904	10 117	— 6 483
1905	19 698	+ 3 008
1906	19 472	+ 2 872
1907	25 510	+ 8 910
1908	13 707	— 2 823
1909	25 996	+ 9 396
1910	14 383	— 2 217
1911	17 824	+ 1 224
Total......	166 027	

Mean = 16 600 000 acre-ft

$$Q' = \frac{16\ 600\ 000}{723} = 23\ 000 \text{ sec-ft.}$$

answer to these questions, and is by far the best discussion of this subject that has yet appeared in engineering literature. Mr. Hazen applies the theory of probabilities in a very ingenious manner. A thorough understanding of that paper is essential to a clear comprehension of parts of the writer's discussion. Figs. 5 and 6 are reproduced from Figs. 26 and 39, of Mr. Hazen's paper. Fig. 5 gives the volume required for regulation during any one water year; Fig. 6 gives the annual storage, P_y, which must be carried over from year to year. The required reservoir capacity, P_m, will be the sum of the two volumes found from Figs. 5 and 6.

FIG. *a*.-MASS CURVE OF COLORADO RIVER, AT YUMA. 10-YEAR PERIOD.

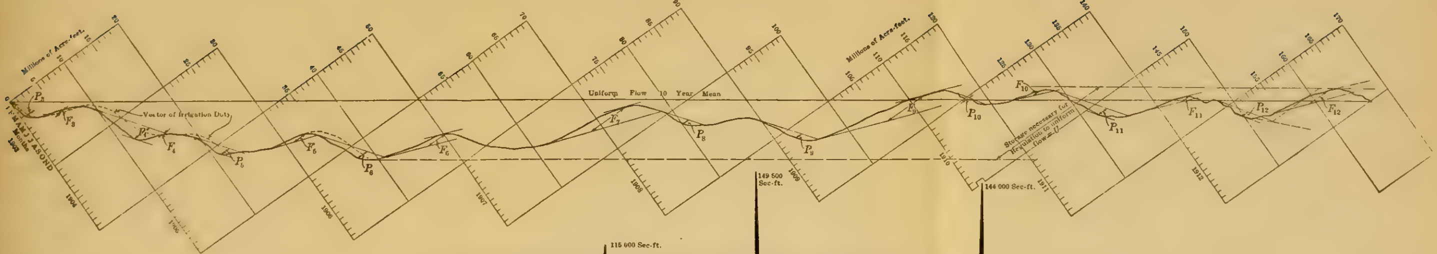
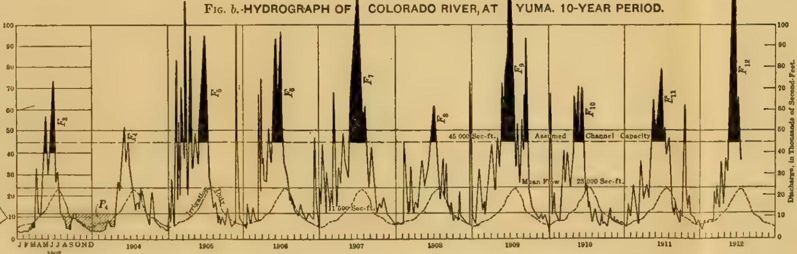


FIG. *b*.-HYDROGRAPH OF COLORADO RIVER, AT YUMA. 10-YEAR PERIOD.

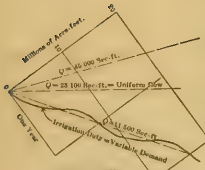


Storage for flood regulation = F_3, F_4, F_5 etc. Maximum = F_7 and F_9

Storage for regulation to 11 500 Sec-ft. = P_3, P_4, etc. Maximum = P_4

" " " " 23 100 Sec-ft., (uniform flow) = U

Relative storage capacities { U
$F_7 = F_9$
P_4



Vectors for Fig. *a*

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The annual storage, P_y, can be determined directly from Fig. 6 for any stream for which the following terms are known:

Q' = mean rate of run-off;

D' = rate of draft;

c = coefficient of variation, $= \frac{V_s}{Q'}$;

V_s = standard variation $= \sqrt{\frac{\Sigma V^2}{n}}$, where V is the difference between the volume of mean yearly run-off and the run-off for any one year;

n = the number of years of record.

Application to the Stream Flow of Plate II.—$C = \frac{V_s}{Q'} = 0.353$, for the data of Table 4, where the values of V are given in the third column. $n = 10$.

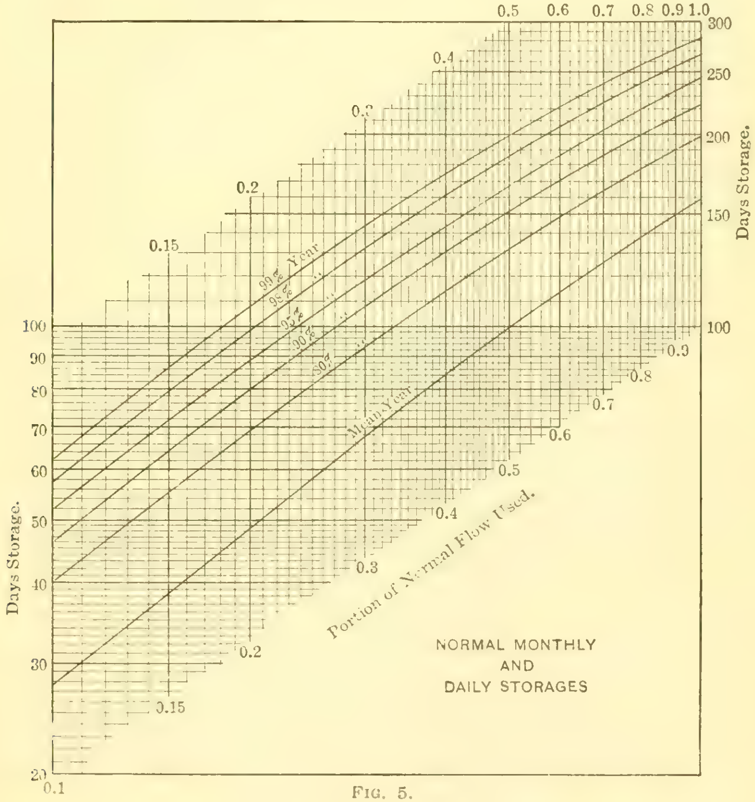

FIG. 5.

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The abscissas of Fig. 6 $= k = \dfrac{Q'\,D'}{c\,Q'} = \dfrac{Q'\,(1 - 0.5)}{Q' \times 0.353} = 1.42$, nearly.

The annual storage requirement for the 95% year is seen to be almost negligible for $k = 1.42$, and would be zero for $k = 1.5$.

The corresponding value of D' is $0.47\ Q'$ (for $k = 1.5$).

This would be the maximum rate of draft to use for low-water regulation for the minimum cost of the reservoir per second-foot of draft. Storage carried over from year to year is not considered economically advisable by many engineers, except for uses where the water has a very high value. The late George W. Rafter, M. Am. Soc. C. E., advises* against the adoption of rates of draft so high that yearly storage is imperative.

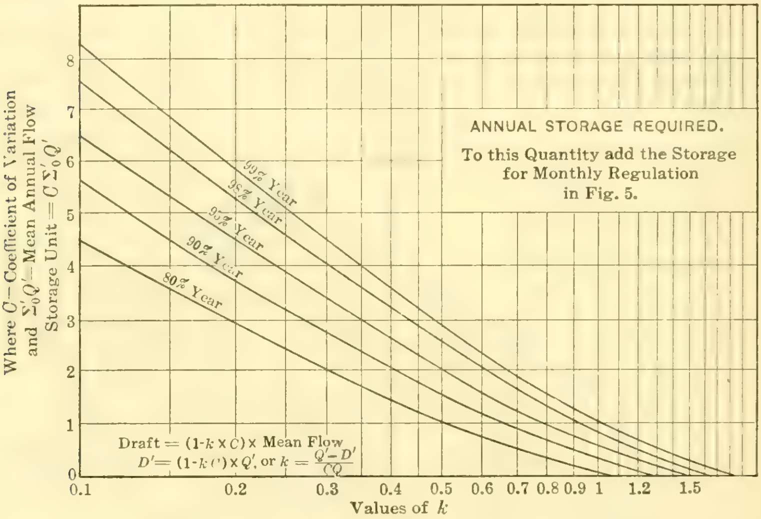

Fig. 6.

The maximum storage for daily and monthly regulation, or for seasonal regulation, may be determined from Fig. 5 by the following procedure:

(1) Determine the mean storage, P', for tne years of record. P' is the arithmetical mean of the maximum values of P for each year. $P' = 1\,083\,000$ acre-ft. for the data of Table 3.

(2) Express P' in days of storage for the draft, D'.

(3) Determine, from the curve of the mean year, Fig. 5, the storage required for the draft, D'. Call this value P'_{NL}.

(4) $P'_{NL} - P'$ = the value to be subtracted from any other curve of Fig. 5, as the curve of the 95% year, or the 98% year, etc., to obtain the probable value of P_m for the conditions of the stream under investigation and the assumed "year of dryness."

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* "Hydrology of the State of New York."

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From Tables 3 and 4, the following values are obtained:

$\Sigma Q' = 16\,600\,000$ acre-ft. per year.

or $Q' = 23\,000$ sec-ft.

$D' = 0.5\,Q' = 11\,500$ sec-ft. $= 22\,800$ acre-ft. per day.

(1) $P' = 1\,083\,000$ acre-ft.

(2) $P' = 47.5$ days storage at rate D'.

From Fig. 5:

(3) $P'_{NL} = 100$ days storage at rate $D' = 0.5Q'$.

(4) $P'_{NL} - P' = 52.5$.

P'_{NL} (95% year) $= 168$ days.

P'_{NL} (98% year) $= 185$ "

Probable storage for stream of Plate II:

P_m (95% year) $= (168 - 52.5)$ days $= 2\,615\,000$ acre-ft.

P_m (98% year) $= (185 - 52.5)$ " $= 3\,022\,000$ acre-ft.

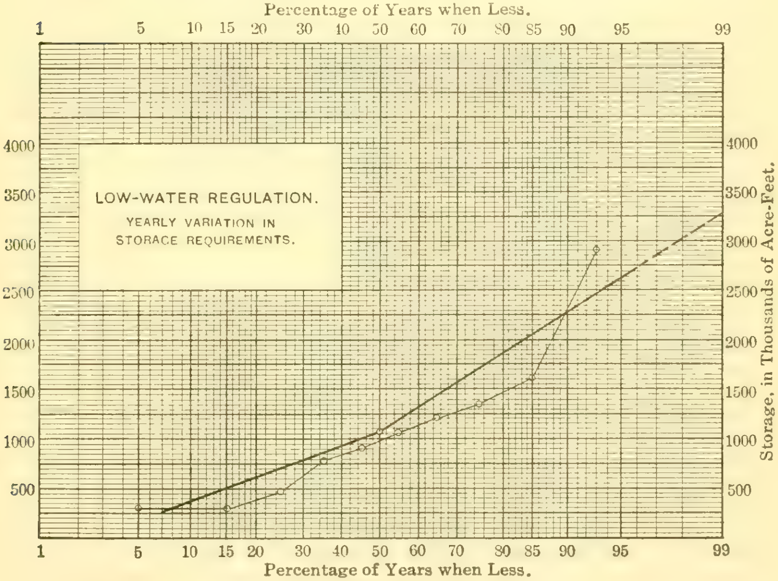

FIG. 7.

To check these results, the data of Table 3 have been platted on probability paper, as shown on Fig. 7. The records are too short to secure a regular curve.

A value of $P_m = 2\,700\,000$ acre-ft. will be selected for the 95% year. Storage based on the 95% year is recommended for general use by Mr. Hazen.

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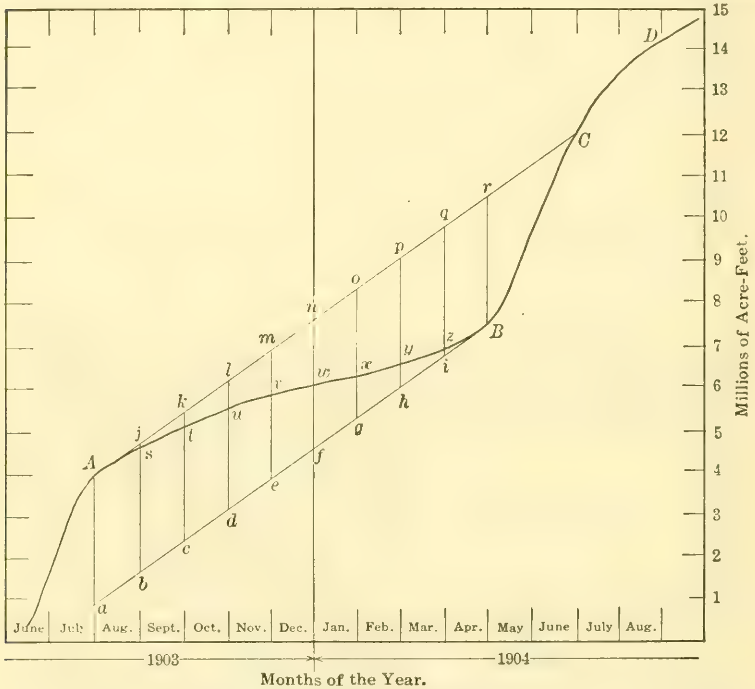
This storage, P_m, is to be used to augment the low-water flow, during periods of deficiency, so that, throughout every year,* a rate of draft, D', may be used safely. Now, it is self-evident that the reservoir should be full at the beginning of the season of low water, but, as water is drawn upon for use, the reservoir becomes gradually depleted, and at the end of the worst season, it will be entirely empty.



STORAGE REQUIREMENT BY MONTHS.

FIG. 8.

Thus, on Fig. 8, the intercept, *r B*, is the same as P_4 of Fig. *a*, Plate II. This represents the maximum storage required for this particular season of low flow (which begins about the end of July, 1903, and ends about the beginning of May, 1904).

The capacity, *r B*, is required at the beginning of the season of low flow; not at its termination. Thus, a volume, $A\,a = r\,B$, must be impounded by the end of July, 1903. The storage volumes necessary at the ends of other months are given in Table 5.

This method was applied to all the 10 years of record, with results as assembled in Table 6.

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* Storage computed for the 95% year signifies that it will be of ample capacity in 95 out of every 100 years; but, during 5 years in a century, a greater volume will be needed.

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TABLE 5.

	End of:									
	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Storage required............	$a\ A$	$b\ s$	$c\ t$	$d\ u$	$e\ v$	$f\ w$	$g\ x$	$h\ y$	$i\ z$	0
Reservoir depletion..........	0	$j\ s$	$k\ t$	$l\ u$	$m\ v$	$n\ w$	$o\ x$	$p\ y$	$q\ z$	$r\ B$

TABLE 6.—Low-Water Regulation.

Required storage,* in thousands of acre-feet, to ensure a sufficient supply during the remainder of the season of low flow. For a draft, $D' = \frac{Q'}{2}$.

Year.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April.
1903	2 700	2 500	2 300	1 900	1 500	800	350	....	....
1904	1 200	1 100	1 000	700	250	950	500	200	....
1905	1 600	1 360	1 120	900	700	....	....	....	....
1906	200	300	300	150	......	300	....	....	....
1907	......	......	......	900	700	....	...	....	....
1908	......	780	600	330	250	350	....	....	....
1909	......	......	300	150	220	100	....	....	....
1910	1 180	870	600	400	100	....	....	....	....
1911	......	......	1 050	950	850	....	....	....	....
1912	450	350	300	250	......	350	....	....	....
Sum.....	7 330	7 260	7 570	6 630	4 570	2 850	850	200	....
Mean....	733	726	757	663	457	285	85	20	....

* Storage at end of each month, or beginning of succeeding month, tabulated. The months in this table are those of deficient flow. May, June, and July always have an excess flow, and it is during this period that the reservoir must be filled. The remainder of the year is one of depletion, during dryest years.

Let P_1 = Probable maximum storage requirement at end of January for 95% year;

P_2 = Probable maximum storage requirement at end of February for 95% year;

P_{12} = Probable maximum storage requirement at end of December for 95% year.

The method of probabilities could be applied to the data compiled, or in Table 6, and the probable maximum storage requirements, P_1, P_2, etc., P_{12}, determined.

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For the stream flow of Plate II, a better method is as follows:

(1) May, June, and July are the months of excess flow, when the reservoir will have to be filled.

(2) The other months of the water years are those of deficient flow, when the water impounded in the reservoir must be drawn upon. The season of deficient flow may be said to begin at the end of July and terminate at the end of April or the beginning of May.

(3) Hence, determine from the run-off records, by applying the theory of probabilities, the probable minimum run-off in the 95% year, for the following periods:

(*a*) April $= \Sigma\ Q_1$.
(*b*) March and April $= \Sigma\ Q_2$.
(*c*) February, March, and April $= \Sigma\ Q_3$.
(*d*) January, February, March, and April $= \Sigma\ Q_4$.
etc., etc., etc.
(*i*) August, September, October, November, December, January, February, March, and April $= \Sigma\ Q_9$.

(4) Let the total draft for each of these periods, in the order listed under (3), be $\Sigma\ D_1$, $\Sigma\ D_2$, $\Sigma\ D_3$, etc.

Then the required storage at the end of each month is as shown in Table 7.

TABLE 7.

End of:	Storage, *P*.	Value of *P*.
July	P_7	$\Sigma\ D_9 - \Sigma\ Q_9$
August	P_8	$\Sigma\ D_8 - \Sigma\ Q_8$
September	P_9	$\Sigma\ D_7 - \Sigma\ Q_7$
October	P_{10}	$\Sigma\ D_6 - \Sigma\ Q_6$
November	P_{11}	$\Sigma\ D_5 - \Sigma\ Q_5$
December	P_{12}	$\Sigma\ D_4 - \Sigma\ Q_4$
January	P_1	$\Sigma\ D_3 - \Sigma\ Q_3$
February	P_2	$\Sigma\ D_2 - \Sigma\ Q_2$
March	P_3	$\Sigma\ D_1 - \Sigma\ Q_1$
April	P_4	0*

* No storage is required by the end of April, or the first of May, because the run-off in May is always in excess of the draft, D'.

This procedure has been carried out, and the results are given in Table 8.

The storage at the end of July is the maximum for which the reservoir need be designed. This volume, P_7, will be taken at 2 700 000 acre-ft.

The argument that the reservoir must be kept full at all times is manifestly illogical. The storage required at the end of March, for

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TABLE 8.—PROBABLE MAXIMUM STORAGE* REQUIRED AT THE END OF EACH MONTH OF THE SEASON OF DEFICIENT FLOW, FOR THE 95% YEAR OF DRYNESS.

Draft = 0.5 Q'. Based on Curves of Fig. 9.

(1)	ΣQ 95% year. (2)	QUANTITIES, IN THOUSANDS OF ACRE-FEET. ΣD (3)	Storage, P, $- \Sigma D - \Sigma Q$ (4)	P (5)	Required at end of: (6)
ΣQ_9	3 550	6 221	2 700* 2 671	P_7	July.
ΣQ_8	2 900	5 515	2 615	P_8	August.
ΣQ_7	2 400	4 831	2 431	P_9	September.
ΣQ_6	2 000	4 125	2 125	P_{10}	October.
ΣQ_5	1 550	3 441	1 891	P_{11}	November.
ΣQ_4	1 250	2 735	1 485	P_{12}	December.
ΣQ_3	890	2 029	1 139	P_1	January.
ΣQ_2	670	1 390	720	P_2	February.
ΣQ_1	320	684	364	P_3	March.

* Figure adopted for maximum, 95% year.

instance, is only enough to tide over the low flow in April. The value, P_3, selected is such that it will be ample in 95 years of every century; and so on for other months, the maximum volume that need be in the reservoir is that tabulated in Column 4 of Table 8.

During what season of each year is this 2 700 000 acre-ft. of water to be impounded? In the 95% year, it is manifestly impossible to secure it during the interval from August 1st to April 30th, as the total run-off is less than the draft by just the amount of this storage. During the dryest years, then, the water must be impounded in May, June, and July, which are the months of replenishment. If the run-off of these 3 months is enough, in the 95% year, to maintain the rate of draft, D', and yet allow of replenishing the reservoir by 2 700 000 acre-ft., it will be more than enough to do this in wetter years.

It should be noted that the minimum flow for any month need not occur in the same year as the minimum flow for 2 or 3 consecutive months, which include the month in question. Also, the minimum run-off during the months of replenishment need not necessarily occur in the same water year as the one requiring maximum reservoir capacity.

The following procedure is then evidently on the safe side:

(1) From the records of run-off during July of each year, determine the probable minimum run-off of the 95% year.
(2) Do the same for the combined run-off of June and July.
(3) Do the same for the combined run-off of May, June and July.

The procedure is similar to that of Fig. 9.

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Let the probable minimum values of the run-off, 95% year, be called:

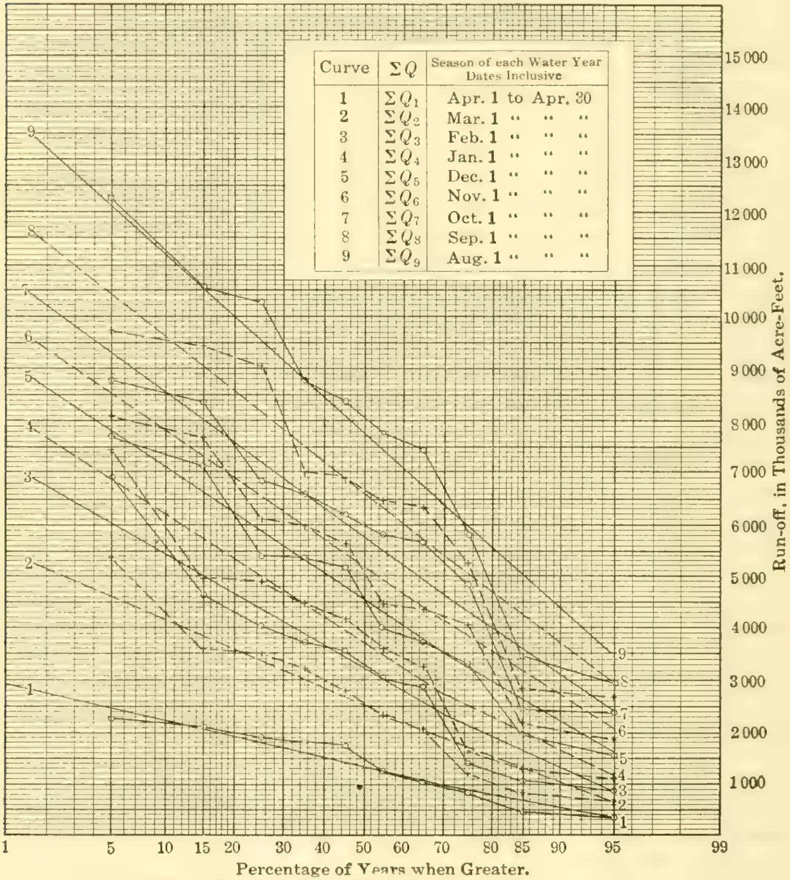
$\Sigma\ Q_A$ for July.

$\Sigma\ Q_B$ " June and July.

$\Sigma\ Q_C$ " May, June, and July.

Also, let $\Sigma\ D_A$, $\Sigma\ D_B$, and $\Sigma\ D_C$ = the draft for the corresponding intervals.

MAGNITUDE OF SEASONAL RUN-OFF IN DIFFERENT WATER YEARS.



Curve	ΣQ	Season of each Water Year Dates Inclusive
1	ΣQ_1	Apr. 1 to Apr. 30
2	ΣQ_2	Mar. 1 " " "
3	ΣQ_3	Feb. 1 " " "
4	ΣQ_4	Jan. 1 " " "
5	ΣQ_5	Dec. 1 " " "
6	ΣQ_6	Nov. 1 " " "
7	ΣQ_7	Oct. 1 " " "
8	ΣQ_8	Sep. 1 " " "
9	ΣQ_9	Aug. 1 " " "

FIG. 9.

Then, $\Sigma\ Q_A - \Sigma\ D_A = P_A$ = storage available during July of the 95% year.

$\Sigma\ Q_B - \Sigma\ D_B = P_B$ = storage available during June and July of the 95% year.

$\Sigma\ Q_C - \Sigma\ D_C = P_C$ = storage available during May, June, and July of the 95% year.

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On the assumption previously made, P_C must be equal to or greater than P_7 = the maximum reservoir capacity.

Results were obtained as shown in Table 9.

TABLE 9.*

Months.	Run-off, 95% year, $= \Sigma Q$.	ΣD	Excess run-off = storage.	
May, June, and July	5 000† 4 800	2 096	2 904 2 704	P_C
June and July	3 000	1 390	1 610	P_B
July	750	706	44	P_A

* Quantities in thousands of acre-feet.

† Probable minimum is in excess of quantity desired, so a smaller value is used.

Storage required in the reservoir by the end of July $= P_C = P_7$.
" " " " " " " " " June $= P_C - P_A = P_6$.
" " " " " " " " " May $= P_C - P_B = P_5$.

Case 1.—From the foregoing:

$$P_5 = P_C - P_B = 1\,094\,000 \text{ acre-ft.}$$
$$P_6 = P_C - P_A = 2\,660\,000 \text{ " "}$$
$$P_7 = P_C \qquad = 2\,704\,000 \text{ " "}$$

P_C is actually 204 000 acre-ft. in excess of the required value of P_7, and a smaller value of ΣQ_C was used than its probable value for the 95% year.

The foregoing procedure, Case 1, determines the largest values of P_5 and P_6 necessary, and is based on a minimum flow for May, June, and July.

Case 2.—The run-off during May will not always permit of a storage of 1 090 000 acre-ft. during that month, as shown by figures in Table 10 based on the 95% year.

TABLE 10.—RUN-OFF AND STORAGE FOR 95% YEAR.

Quantities, in thousands of second-feet.

Months.	Run-off in 95% year, $= \Sigma Q$.	ΣD	Excess run-off = possible storage.	
May	1 600	706	894	P_5
May and June	3 850	1 390	2 460	P_6
May, June, and July	4 800	2 096	2 704	P_7

Mr. Petterson.

TABLE 11.—COMPARISON OF CASES 1 AND 2.

	VALUES OF P, IN THOUSANDS OF ACRE-FEET.		INCREMENT OF STORAGE DURING EACH MONTH.		
	Case 1.	Case 2.	Case 1.	Case 2.	Month.
P_5	1 094	894	1 094	894	May.
P_6	2 660	2 460	1 566	1 566	June.
P_7	2 704	2 704	44	244	July.

The apparent discrepancy is explained by the plausible supposition that the minimum run-off for May will not occur in the same year as the minimum run-off for July.

B.—Reservoir Capacity for High-Water Regulation Only.

As in the case of low-water regulation, the capacity of a reservoir for high-water regulation, or flood prevention, depends on the run-off and the rate of draft.

The draft for high-water regulation is the rate which can be discharged safely from the reservoir during the flood period. This rate will be called q. The maximum possible value of q is equal to the safe carrying capacity of the river channel below the reservoir. $\Sigma^T_0 (Q - q) = F$, the storage required for any flood.

Here T represents the duration of the flood, or the time in which Q is greater than q.

F obviously depends on the duration of high waters as well as on the intensity of flow. This is well illustrated in Figs. *a* and *b* of Plate II, where the assumed value of $q = 45\,000$ sec-ft. The volumes of F are proportional to the shaded areas in Fig. *b*. In Fig. *a* some of the floods of high intensity are seen to require a very small storage volume.

Seasonal Occurrence of Floods.—A great deal might be written on the seasonal occurrence of floods, but only one idea will be discussed.

Granting that floods may occur at any time on a particular river, it is practically universally true that there is a prevailing season when the maximum floods arise. This is particularly true if, by maximum floods, we mean those requiring the largest storage volume to regulate to safe flow, q.

In Table 12 is assembled the capacities, F, for all the floods during the 8 years of records. The storage is written under the month in which the flood began.

It will be seen that all the larger floods began some time in May. These larger floods are of long duration, and last well into July. Only the month in which the floods commence is of importance, however, as will be seen later in the discussion of a reservoir for both low- and high-water regulation.

Mr. Petterson.

The storage capacity required for the largest floods of each year is plotted on Fig. 10 for the purpose of determining the probable capacity, F_m, for the 95% year. From Fig. 10 it is taken as 7 150 000 acre-ft.

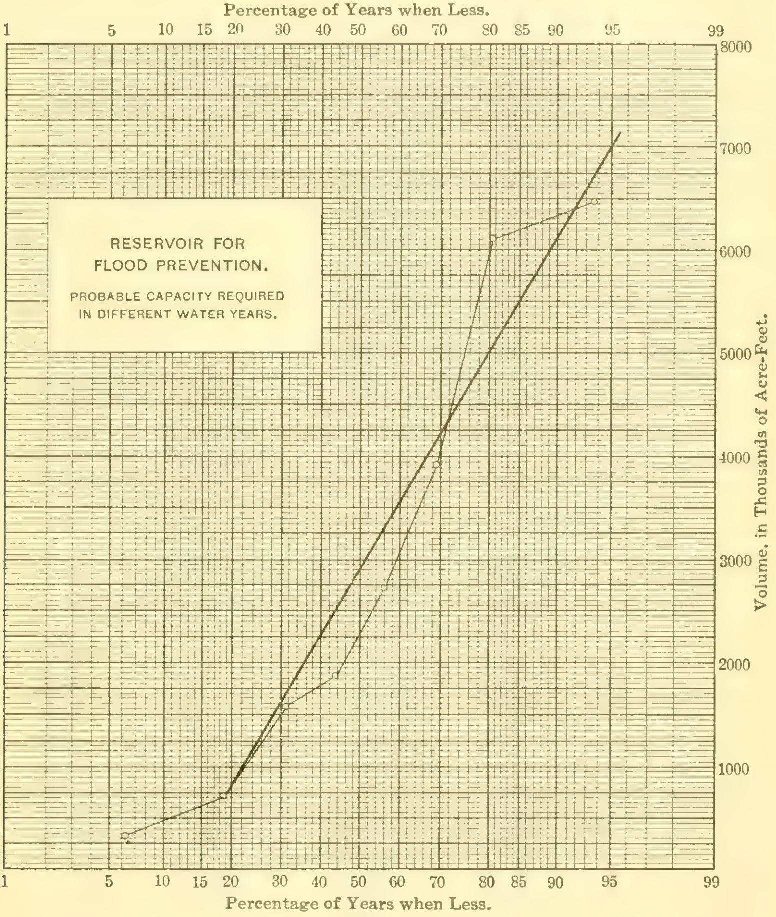

FIG. 10.

In the same way, the probable maximum capacities in the 95% year, for floods commencing in each of the months might be obtained. In the case of the data of Table 12, this procedure is not feasible because of the many blanks in the record, or years when no floods occur during such months.

Mr. Petterson. As a rough approximation—which does not pretend to any reasonable degree of truth, but errs grossly on the side of safety—the curves for each month were assumed to be parallel to the regular line of Fig. 10, and to pass through the mean value in the 50% line. The quantities of Table 13 were thus obtained. There is no doubt that the values of F listed in Table 13, with the exception of F_5, are much larger than they should be. However, it was desired to err on the safe side.

TABLE 12.—STORAGE CAPACITY, IN THOUSANDS OF ACRE-FEET, FOR FLOODS BEGINNING DURING ANY MONTH.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1905	....	123.9	591.0	251.1	1 850	....	....	....	....	....	213 0	29.7
1906	....	....	105.1	....	2 700	....	....	....	....	....	....	.....
1907	....	....	47.2	43.2	6 450	....	....	....	....	....	....	.....
1908	....	....	....	....	......	328.0	....	....	....	....	....	101.9
1909	....	....	....	5.7	6 100	....	....	63.4	651.0	....	....	.....
1910	71.9	....	....	....	719.0	385.5	....	....	....	....	....	.....
1911	....	....	....	....	1 560	....	....	....	....	92.3	....	.....
1912	....	....	....	....	3 900	....	....	....	....	....	....	.....
Summation	71.9	123.9	743.3	300.0	23 279	713.5	....	63.4	651.0	92.3	213.0	131.6
Mean	9.0	15.5	92.9	37.5	2 910	89.1	....	7.9	81.4	11.5	26 6	16.4

TABLE 13.—FLOOD PREVENTION RESERVOIR.—MAXIMUM ASSUMED STORAGE, IN THOUSANDS OF ACRE-FEET, FOR 95% YEAR, FOR FLOODS BEGINNING IN MONTHS LISTED.

Month.	From records. (*a*)	Probable 95% year.* (*b*)		Ratio, $\frac{(b)}{(a)}$
January	71.9	4 249	F_1	59
February	123.9	4 255	F_2	34.3
March	591.0	4 333	F_3	7.32
April	251.1	4 277	F_4	17.05
May	645.0	7 150†	F_5	1.108
June	385.5	4 339	F_6	11.24
July	.....	4 240	F_7	......
August	63.4	4 248	F_8	67
September	651.0	4 321	F_9	6.64
October	92.3	4 252	F_{10}	46.1
November	213.0	4 267	F_{11}	20
December	101.9	4 256	F_{12}	41.8

* Figures for all months but May obtained by adding (7 150–2 910) = 4 240 to the mean quantities of Table 12, 4 240 = difference between maximum and mean of floods commencing in May

† From Fig. 10.

Mr. Petterson.

C.—Reservoir Capacity for the Combined Function of Both High-Water and Low-Water Regulation.

If a reservoir had a quantity, P, impounded at the beginning of a flood flow, and a volume, F, were required to regulate the high water to safe flow, q, the combined capacity of the reservoir would evidently be $V_c = F + P$. Now, the required maximum capacities that need be stored in the reservoir at the end of each month have already been determined, and are equal to P_1, P_2, . . . P_{12}.

The maximum probable values of F, for floods commencing in any month are also assumed to be known. If the flood commences in the earlier part of the month, the quantity, P, already stored is equal to that required at the end of the preceding month; and, if the flood begins near the end of any month, the quantity, P, impounded is that required at the end of that month.

In Table 14 the combinations of F and P, for any month, that will give the greater result are listed.

The capacity, V_c, for which the composite reservoir having a dual function must be designed, is the maximum of these combinations of $F + P$, and is found to be 8 240 000 acre-ft.

TABLE 14.—STORAGE CAPACITIES, F, AND P, AND $F + P$, IN THOUSANDS OF ACRE-FEET.

	F	P		$F + P$
F_1	4 249	1 485	P_{12}	5 734
F_2	4 255	1 159	P_1	5 394
F_3	4 333	720	P_2	5 053
F_4	4 277	364	P_3	4 641
F_5	7 150	.....	P_4	7 150
	7 150	1 090	P_5	8 240
F_6	4 339	1 090	P_5	5 429
		2 660	P_6	6 999
F_7	4 240	2 700	P_7	6 940
F_8	4 248	2 700	P_7	6 948
F_9	4 321	2 615	P_8	6 936
F_{10}	4 252	2 431	P_9	6 683
F_{11}	4 267	2 125	P_{10}	6 392
F_{12}	4 256	1 891	P_{11}	6 147

Summary of Results.—The following gives the required storage, in thousands of acre-feet:

(A) Reservoir for low-water regulation only..... $= P_m = 2700$
(B) " " flood prevention only......... $= F_m = 7150$
(C) " " combined function of A and B. $= V_c = 8240$
Sum of $P_m + F_m$.................................... $= 9850$
Saving in capacity by using composite reservoir......... $= 1610$
or $V_c = F_m + 0.403 P_m$.

Mr. Petterson.

In general, $V_c = F_m + bP_m$, where b will always be less than 1 and frequently will be less than 0.5. Further generalizations cannot be made. The hydrologic data of each water-shed must be given individual study.

In case a larger rate of draft, D, were assumed, so that a yearly storage, P_y, is required, in addition to that for seasonal or monthly regulation, it would be added to the values of P_1, P_2, etc., so that P_m would be increased by the amount, P_y, as would also V_c.

If the draft, D', is increased greatly, it will be found that as D' approaches its limit, Q', the reservoir must of necessity act as a regulator of both high and low flows. It must store all excess run-off, in order to impound an adequate supply for the seasons of low water.

The volume, designated as U on Fig. *a* of Plate II, is that required to regulate to uniform flow, or where $D' = Q'$. This storage is nearly 19 000 000 acre-ft., or about seven times the storage necessary to regulate to a draft, $D' = 0.5\ Q'$, and 2.3 times the capacity determined for V_c, for combined flood prevention and low-water regulation to a draft of one-half of the mean flow.

With the lower rates of draft, the storage, P_m, is small, and F_m is relatively large, but, with the higher rates of draft, P_m becomes larger than F_m. Finally, F_m = zero and $P_m = V_c$, because all flood flows must be conserved in order to provide the water which is to sustain the draft.

D.—Operation of a Reservoir Having the Dual Function of Preventing Floods and Storing Water for Use.

The storage quantities computed in "A" are those required for the worst conditions assumed. In years of greater run-off a less quantity could be safely impounded, but wet and dry years cannot be safely predicted. No weather prediction whatever is needed, however. The reservoir operator is given instructions somewhat as follows:

Conserve all run-off during each month* of replenishment until the required volume of water for that month is impounded.

As soon as the required volume has been impounded, all excess inflow may be wasted.

The volume of water which must be in the reservoir by the end of each month, has been determined before the reservoir was built. A table can be given to the operator, with these volumes expressed in height of water surface. He has only to observe water elevations on a graduated rod or gauge.

Thus, for the theoretical reservoir discussed herein: On May 1st commence conserving all excess run-off until the storage, P_5, has been

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* These are May, June, and July for the stream studied. The particular months will always be known for any stream.

Mr. Petterson.

accumulated. If the volume, P_5, has been accumulated before the end of May, the remaining inflow may be wasted. There is no need of a greater volume before June 1st.

During June conserve all excess run-off until a water level is reached corresponding to the storage, P_6. Maintain this level until July 1st.

Of course, if the level for storage, P_5, say, has been reached early in May and shortly afterward a heavy and prolonged run-off ensues, far in excess of maximum allowable outflow, the reservoir level will rise. If the flood flow is exceptional, the reservoir (of volume, V_c) may be completely filled; but such contingencies have been provided for in determining the volume, V_c.

The reservoir being assumed to be completely filled, or with water level higher than necessary for any month, it would be depleted at the rate,* $q + D'$, until the required level was reached.

The reservoir capacity, V_c, was designed for the 95% year. Floods may occur—at rare intervals—which would overtax this capacity. The writer believes that the spillway should be designed for such contingencies that the volume above the spillway overflow may exert its reductive effect after the reservoir has been filled; in other words, that flood prevention reservoirs, of the type discussed by the author, should be considered as a safety factor and not as the main defense. The writer believes that "Impeding Reservoirs" would be a better name for basins of this class, with spillway outlets, to distinguish them from "Detention Basins" with orifice outlets. The ideal reservoir for flood prevention and storage for use would thus be a composite reservoir, consisting of:

1.—A lower volume of capacity, P_m, which is a storage reservoir, but differing from previous conceptions, in that the water level does not need to be kept at a fixed elevation, but varies from month to month. Also, large controlled outlets should be provided to allow of wasting this water when desired.

2.—An upper volume, of capacity, $V_c - P_m$, with orifice outlets. This portion is a detention basin.

3.—The temporary storage above the overflow, provided as a factor of safety.

To repeat, in closing: The lower storage basin, of volume, P_m, allotted for low-water regulation, does not have to be kept full at all times, but can be operated on a definite schedule of water levels and time.

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* Discharge, q, through wasteways or gates.
" D, through controlled outlets to conduit, or pipe lines.

Mr. Petterson.

If the prevailing season for worst floods does not synchronize with a full storage basin, a considerable part of the volume, P_m, is available for storing flood waters, and the volume of the detention basin may be reduced accordingly. The capacity of the composite reservoir, therefore, may be considerably less than the combined volumes of two separate reservoirs, one of which is used for low-water regulation only, and the other is utilized for flood prevention only.

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PAPERS AND DISCUSSIONS

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A PHENOMENAL LAND SLIDE—SUPPLEMENT

Discussion.*

By D. D. Clarke, M. Am. Soc. C. E.†

D. D. Clarke,‡ M. Am. Soc. C. E. (by letter).§—The writer desires to put on record his deep appreciation of the kindness of Mr. Dillman in submitting such an interesting résumé of this paper and of the whole slide situation so far as it has been developed along the Pacific Coast during recent years. Mr. Clarke.

The writer has been more or less familiar with several of the slides mentioned by Mr. Dillman, but others are not well known. It is to be hoped that some day additional information may be available regarding the Cascade Slide, and also the upheaval which occurred at Lake Crescent, Washington. The entire Profession is indebted to Mr. Dillman for his interesting statements regarding the number and cause of the slides on the Pacific Coast, and he will be quoted as an authority on this subject.

Attention is called to an interesting account of the immense slide on the Fraser River, British Columbia, by Robert Brewster Stanton, M. Am. Soc. C. E.‖

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* Discussion of the paper by D. D. Clarke, M. Am. Soc. C. E., continued from January, 1918, *Proceedings*.

† Author's closure.

‡ Portland, Ore.

§ Received by the Secretary, April 22d, 1918.

‖ *The Engineer* (London, England), December 14th, 1897.

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A BRIEF REVIEW OF TRIGONOMETRICAL MATHEMATICAL TABLES, AND A CONTEMPLATION OF THE SPECIFICATIONS FOR TRIGONOMETRICAL TABLES FOR GENERAL USE

Discussion.*

BY MESSRS. GEORGE A. CHRISTENSEN AND VIRGIL A. EBERLY.†

GEORGE A. CHRISTENSEN‡, ASSOC. M. AM. SOC. C. E. (by letter).§—The writer believes that a well-arranged set of tables, in convenient book form, and in accordance with the lines proposed, would be of great value to the Profession. It is generally realized, of course, that to edit such a book would be a work of love, and not one for profit. Mr. Raymond's comments have added practical specifications to the premises, and should be observed in case such a book of tables is prepared. Mr. Christensen.

Attention is invited to Fig. 1 reproduced from a photograph showing an arrangement of multiplication tables, which could be applied to any table of natural or logarithmic functions. The writer has experimented with logarithmic tables arranged after this form, and has found that they could be used more expeditiously than the con-

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* Discussion of the paper by Virgil A. Eberly, Assoc. M. Am. Soc. C. E., continued from January, 1918, *Proceedings*.

† Author's closure.

‡ San Diego, Cal.

§ Received by the Secretary, April 2d, 1918.

Mr. Christensen ventional form. This is true, also, of tables of natural functions, or of any other mathematical tables capable of being arranged in groups, as shown in Fig. 1. The advantage lies in the logical arrangement, the prominence of the index number, and that all numbers—for example, 1 to 100—are found on the two pages where the book opens. All functions pertaining to the index number with its decimals are located by arguments which are decimal co-ordinates, so to speak, of the functions sought. In this way any desired number is very readily found. The ten indexes are divided into two parts, forming the left-hand and right-hand pages of the book wherever it is opened.

Attention is called to the form of index cutting of the book shown by Fig. 1. By actual trial it is found that the book can be rapidly leafed through, and any desired page quickly found by using only one hand. Another novelty is that the book is left-handed; it is operated with the left hand, the right hand being free to use the pencil or pen to make notations; it is truly a one-handed, left-handed affair. As an office appliance, it makes for efficiency, and, if a book of mathematical tables, such as proposed by Mr. Eberly, is published, the writer would recommend that the form described herein be adopted. The book was compiled by the writer, and a copy may be found in the Engineering Societies Library.

Mr. Eberly. VIRGIL A. EBERLY,* ASSOC. M. AM. SOC. C. E. (by letter).†—The writer is obliged to concede that the tables he proposes would not be useful to all classes of computers, as the title of the paper indicated. Nevertheless, for triangulation, precise surveying, or structural work involving large numbers of connected triangles, such tables would save much time where the computing machine is used. He wishes particularly to emphasize the fact that the need of such tables has been brought about by the use of computing machines.

Such machines require a decimal system unless they are used for addition and subtraction only, and if their use is thus restricted, they lose much of their value; besides, special machines departing from the decimal system are costly and of limited use. The solution of triangles calls for a machine with decimal arrangement, capable of performing multiplication, division, and extraction of square root. The machine, in turn, calls for a decimal division of the unit.

Mr. E. V. Huntington, of Harvard University, has compiled and published four-place tables using a decimal division of the degree, and has five-place tables in course of preparation, which, together with the fact that Mr. Raymond has published similar tables, would show that they are no longer experimental. The tables published by Mr. Huntington and Mr. Raymond do not possess all the facilities for

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* Washington, D. C.

† Received by the Secretary, March 30th, 1918.

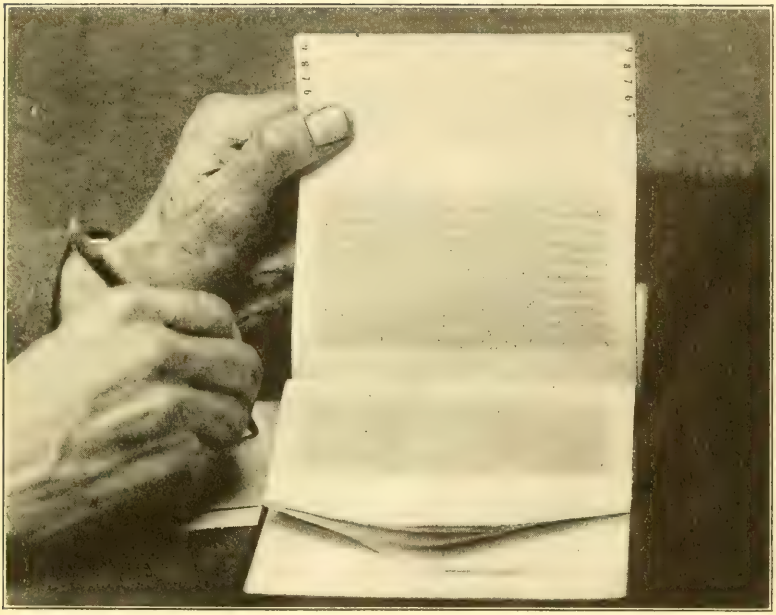

Fig. 1.—Arrangement of a Book of Tables.

Mr. Eberly.

interpolation, nor, in the number of canons, are they as extensive as those proposed by the writer.

Answering the question as to the method of interpolation, raised by Mr. Andrews, the writer prefers only the differences between consecutive values, set half way between the values. These differences are absolutely essential to speed with the computing machine, and are all that are required, under any circumstances, with a machine.

The writer agrees with Mr. Raymond that five-place require less time to operate than seven-place tables, but this difference is much less when a computing machine is used. Besides, the writer finds that, with a seven-place canon having differences between consecutive values listed, much greater speed can be obtained than with a five-place canon without such differences, when it is necessary to interpolate, as frequently occurs in the classes of work indicated previously. This refers, of course, to use with a computing machine.

The objection which Mr. Raymond urges, of having 100 arguments per page, involves that which may be urged against many books of tables, namely, that the required length is somewhat great. However, the writer believes that the advantage of having one degree per page would offset this disadvantage. The book would not have the disadvantage of many works, that is, too great thickness, as it would have less than 500 pages. If the work were given the same size of type as that used in the natural functions in "Mathematical Tables",* with the same groups of five arguments and size of page margins, a page 11¼ in. deep would be required. The writer cannot see that such type would be too small, as tables are generally used with a straightedge, regardless of the size of type. The five-group is much preferable to the ten-group arrangement.

The writer intended to state in the paper that, in case thumb-indexing is used, it should be confined to the different canons only, and not to the various degrees under one canon, as the latter would be so numerous as to render it worthless. The writer believes that an arrangement such as suggested by Mr. Christensen could be devised which, if tough, heavy paper was used, would be preferable to ordinary thumb-indexing.

He does not see that the question of the number of degrees per quadrant affects the situation, but adheres to the preference for 90, because the latter will save much interpolation.

The tables which are available for the classes of work previously mentioned, are not well adapted to the computing machine, principally because they were compiled before the day of the latter. Machines are now available at a cost of $250 or $300, and render the computation of work at a speed undreamed of when the tables now in use

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* Edited by James Pryde, and published by W. and R. Chambers, London, 1899.

Mr. Eberly. were compiled. The saving in time and accuracy soon overbalances the cost of the machine.

Referring to the question of the number of places in the tables, it is desired to remind Mr. Andrews that a seven-place value is the largest that one can accurately carry in mind. This should be given due consideration in the compilation of a proposed work.

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VERIFICATION OF THE BAZIN WEIR FORMULA BY HYDRO-CHEMICAL GAUGINGS

Discussion.*

By Frederic P. Stearns, Past-President, Am. Soc. C. E.

Frederic P. Stearns,† Past-President, Am. Soc. C. E.—Before discussing this paper in detail, it seems appropriate to review briefly the results of the principal weir experiments which have been made, showing, among other things, the great variation between the results obtained by different experimenters. These differences are shown graphically on the diagram (Fig. 25), which may assist to an understanding of the discussion. Mr. Stearns.

In this review it is hardly necessary to go farther back than to the experiments of the late James B. Francis,‡ Past-President, Am. Soc. C. E., made in 1852, which introduced a new epoch in weir experiments. They were made on a large scale, with extreme accuracy, and covered a wide variety of conditions. He determined the discharge over weirs with and without end contractions, with heads on the weir ranging from 0.59 to 1.58 ft., and with varying heights of weir above the bottom of the channel.

These experiments were described in much detail, and a careful reading of the description furnishes strong evidence that everything possible was done to secure accurate results. The conditions under which they were performed were in most respects excellent. The close agreement of the deduced coefficients for each experiment with the general result of all experiments furnishes further confirmation of the accuracy of the work.

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* Discussion of the paper by Floyd A. Nagler, Jun. Am. Soc. C. E., continued from March, 1918, *Proceedings*.

† Boston, Mass.

‡ "Lowell Hydraulic Experiments."

Mr. Stearns. One of the first indications, based on careful tests, that a weir measurement might not be as accurate as was supposed, resulted from the experiments made by Fteley and Stearns on a 5-ft. weir,* in 1877. This weir in all its features was clearly well within the limitations set forth by Francis as necessary for the accurate application of his formula. The conditions for making these experiments were excellent, and most of the experiments gave results agreeing with the formula, representing them within 0.1 of 1%, but the discharges with heads on the weir corresponding to those in the experiments of Francis exceeded his by fully 0.5 of 1 per cent.

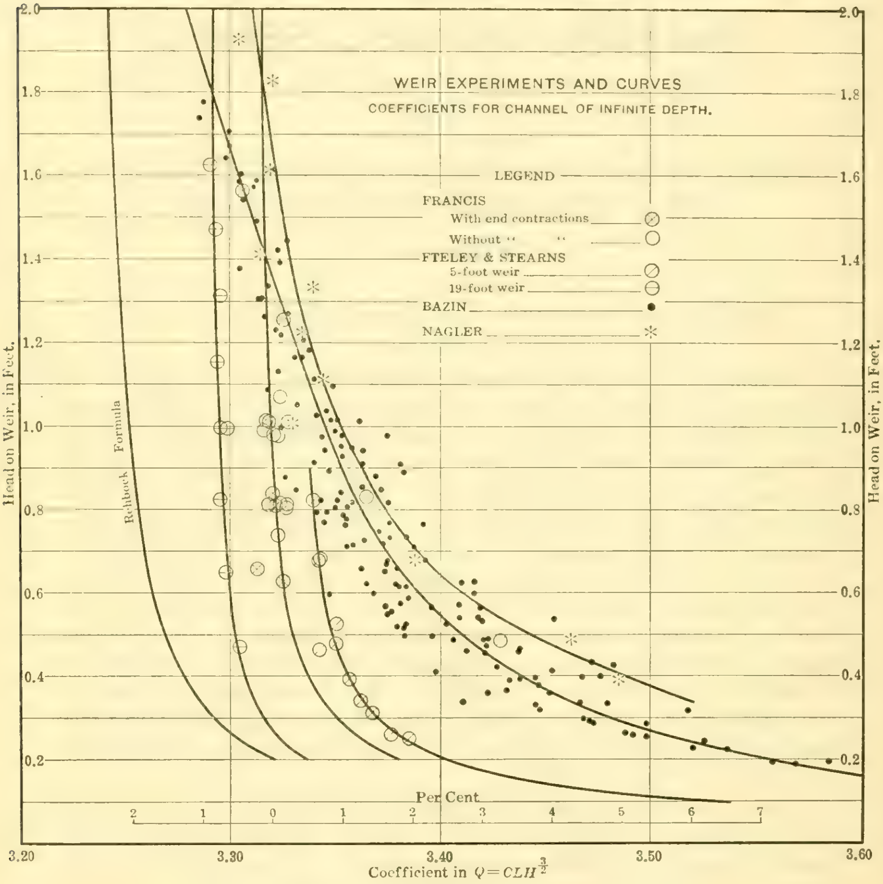

FIG. 25.

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* "Description of Some Experiments on the Flow of Water Made During the Construction of Works for Conveying the Water of Sudbury River to Boston", by A. Fteley and F. P. Stearns, *Transactions*, Am. Soc. C. E., Vol. XII (1883), p. 1.

Mr. Stearns.

The next series of experiments was that of Fteley and Stearns, in 1879, on a 19-ft. weir, 6.55 ft. in height. These experiments were made for the purpose of calibrating the weir so that it might be used subsequently for determining the discharge through the Sudbury Aqueduct and for testing the accuracy of a current meter.

The weir was necessarily placed in a very short channel in a gate-house at the head of the aqueduct, the length of the channel from the point of a stone pier in the middle of the structure to the head wall of the aqueduct being only 8.25 ft. In order to furnish the required space below the weir for the discharge of the water, it was necessary to place the crest about 6 ft. from the end of the pier. On each side, an additional distance was available, but the lower screens were only 7.45 ft. up stream from the weir.

In view of these abnormal conditions, it was expected that the results obtained by this weir might vary considerably from those obtained under normal conditions; but, with the smallest head covered by the experiments, the flow of water to the weir appeared to be so regular and the velocity of approach so small (0.151 ft. per sec.) that it was thought the results obtained with small heads might be normal.

The experiments produced a consistent series of coefficients for all heads on the weir, but they were about 0.7 of 1% smaller than those determined from the experiments of Francis, and, therefore, about 1.2% smaller than those determined from the 5-ft. weir. Aside from the abnormal conditions due to the short channel, the conditions under which these experiments were made were ideal.

The next set of experiments to cause additional doubt as to the accuracy of weir measurements was that of Bazin* on standard weirs having lengths of 6.56, 3.28, and 1.64 ft., respectively, and a height of weir above the bottom of the channel of 3.72 ft. for the first two and 3.30 ft. for the last.

These experiments were made under favorable conditions, in some respects, as the channel of approach was of good length, and there was a good measuring basin; in other respects, the conditions were unfavorable, as no provision appears to have been made for stopping oscillations or for regulating the velocities in the channel by using screens. Bazin states that, even in the stilling basin at the side of the channel, the oscillations were such that it was not feasible to determine the head on the weir by the hook-gauge alone, and he therefore used a dial operated by a float for this purpose, making comparisons, however, during an experiment, between the readings of the dial and of the hook-gauge, in order to get the proper relation to the crest of the weir.

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* "Expériences Nouvelles sur l'Ecoulement on Déversoir", by H. Bazin, *Annales des Ponts et Chaussées,* 1888. Translation by Marichal and Trautwine, *Proceedings,* Engineers Club of Philadelphia, Vol. 7, pp. 259–310.

Mr. Stearns. As might be expected, under these conditions, the individual experiments do not follow closely the formula or curve representing the mean result, but the experiments are numerous, and their mean result with different heads on the weir is well indicated and consistent. This mean result agrees fairly well with the general result of the experiments of Francis when the head on the weir is about 1.5 ft., but exceeds his result by about 2% when the head is between 0.5 and 0.6 ft.

A much more recent set of experiments is that made by Th. Rehbock* in the hydraulic engineering laboratory of the Technical University in Karlsruhe. The speaker is indebted to Professor Lewis F. Moody, Consulting Engineer, for a translation of two short papers by Rehbock, describing the results of his experiments.

The experiments were carried on for several years, with an improvement in the testing outfit, from time to time, in the methods of experimenting, and in the accuracy of the observations, so that the paper of 1912 states that "the exactness of the results cannot be exceeded". In this paper, a formula is given for the discharge over standard sharp-edged weirs, with contractions suppressed.

The paper of 1913 states that it was decided to repeat the tests in order to make sure that the formula of 1912 was absolutely exact, and, after making 191 additional tests, it was found that it was sufficiently correct for all practical cases except for heads on the weir less than 0.09 ft. By changing the formula slightly, it was found that it would apply correctly to smaller depths on the weir.

The experiments were on a small scale, the heads on the weir ranging from 0.03 to 0.59 ft., and the height of the crest of the weir above the bottom of the channel varying from 0.41 to 1.64 ft. The length of the standard weir was 1.64 ft., but tests were also made on a shorter weir. The individual experiments are not given; hence, in preparing the diagram (Fig. 25) only the line representing the formula could be shown.

Rehbock's results with heads on the weir of from 0.5 to 0.6 ft. are nearly 2% less than those of Francis. Hence, the inclusion of his results gives a range of experimental coefficients, obtained by different experimenters with these depths on the weir, of about 4 per cent.

Rehbock calls attention to weir experiments by Hansen, and shows their results by a diagram which indicates that Hansen's results with depths of from 0.5 to 0.6 ft. are 0.7 of 1% less than his, so that the range between Hansen and Bazin with these depths is about 4.7 per cent.

The next series of weir experiments is the one under discussion, and the precedent set by all other experimenters of obtaining results

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* *Zeitschrift* des Verbandes Deutscher Architekten- und Ingenieur-Vereine, 1912, Pt. 1; 1913, Pt. 1.

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with depths on the weir of about 0.6 ft. beyond the limits reached by any previous experimenter remains unbroken. The author's results with this depth on the weir are about 2.5% greater than those of Francis, and consequently 4.5% greater than those of Rehbock, and more than 5% greater than those of Hansen. This is the present record for variation in weir coefficients with this depth on the weir, and it remains to be seen whether the next experimenter will be able to obtain results which will widen the range still farther.

In view of these large differences in the results of carefully conducted weir experiments, two conclusions seem to be warranted:

(1) That in the present state of the art the weir is not an accurate instrument for the measurement of water;
(2) That the art should be developed so that the causes of the variation in results may be discovered and eliminated.

It is much easier to ask the question, "What are the causes of these variations?" than to offer even a partial solution of the problem. The subject may be discussed profitably, even if the result is only to eliminate certain factors which are not the causes.

Notwithstanding the tendency which develops at times to accept a given weir formula and to ignore the results of others, on the ground that they are less trustworthy, it must be clear to those who have carefully examined the descriptions of experiments which have been made, that the variations, as a rule, are not the result of inaccuracy of physical measurements, except possibly with very small heads.

Clearly it is not difficult to measure within a small fraction of 1% the length of a weir, the size of a measuring basin, or the interval of time required for the discharge from a weir to fill the basin if it is of sufficient size; and, as a rule, the basins have been of ample size, especially with moderate heads on the weir. The measurement of the head on the weir with a similar degree of accuracy is more difficult, but this may be accomplished, and has been accomplished even with small heads.

There is sometimes a small leakage from or into a measuring basin, but this is easily determined by observing the rate at which the water lowers before the experiment is made and after it is concluded, so that a correction practically free from error may be made.

It is customary not to empty a measuring basin completely, but to determine the volume between two water levels. In a long basin, oscillation from end to end, especially after the experiment is finished, cannot be wholly prevented, but the elevation of the water can be determined each minute for a sufficient length of time to cover one or several complete oscillations, and in this way get the correct level with minute accuracy.

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As an illustration of the accuracy of such work under extreme conditions there may be cited the case of a measuring basin about 2 miles in length, where the distance between the two water levels was measured at three points with closely agreeing results. In measurements made on November 28th, 1879, the difference in levels by three gauges was as follows:

Gauge 1	2.9632
" 2	2.9620
" 3	2.9582
Average	2.9611

The maximum difference from the average is 0.0029, or about 0.1 of 1%, and the average is probably still nearer the correct quantity.

An analysis of all the features of the more important weir experiments where the discharge into a basin has been measured shows that the discrepancies, except possibly those incidental to small heads, cannot be attributed to errors in physical measurements, and, therefore, their causes must be sought in the conditions under which the experiments were made.

It seems likely that the most important causes of the differences may be found in the differing motions of the water in the channel approaching the weir, in the manner of taking the head on the weir, and in the oscillations occurring in the surface of the water in the weir channel.

In the future much more attention than has been given in the past should be devoted to the regulation of the relative velocities of the water in different parts of the cross-section of the channel of approach, as there is some reason to believe that this is an important factor affecting the discharging capacity.

The speaker made a study of the motions of the water in the weir channel in connection with the experiments of Fteley and Stearns on the effect of velocity of approach. Where there is a long channel of approach to a weir without end contractions, the water moves forward without being affected in any way by the presence of the weir until it reaches a point distant from the weir about 2½ times its height above the bottom of the channel; then, at the bottom of the channel, the retarding effect of the weir begins to be felt to an increasing extent as the water approaches the weir. This has been shown by measuring with a current meter the velocity of the water at the bottom of the channel at various distances from the weir.

The retardation of the current at the bottom of the channel is accompanied by an increase of pressure, so that there is in the angle between the weir and the bottom of the channel, what may be called an angle of pressure, where the head is in excess of that corresponding to the height of the surface of the water in the channel above the point where the surface curvature begins.

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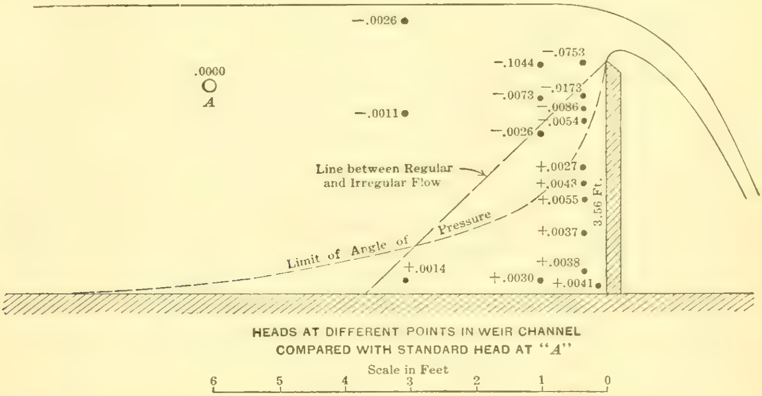
Fig. 26 shows the approximate limits of the angle of pressure and the extent of the pressure within it, as determined at several points when the head on the weir was 0.8047 ft., and the velocity head due to the mean velocity in the channel of approach 0.0049 ft. The figures shown are decimals of a foot, those with the plus sign showing a pressure greater than the height of the surface of the water at a point 6 ft. up stream from the weir, and those with the minus sign a pressure smaller than that 6 ft. from the weir.

The line drawn at an angle of 45° from the crest of the weir to the bottom of the channel limits approximately the triangular area in which there are irregular motions, rather than a steady current toward the weir opening, a subject which will be discussed subsequently.



−.0026
.0000
A
−.0011
−.1044
−.0753
−.0073
−.0173
−.0086
−.0054
−.0026
Line between Regular and Irregular Flow
+.0027
+.0043
+.0055
+.0037
+.0038
+.0030
+.0041
+.0014
Limit of Angle of Pressure
3.56 Ft.
HEADS AT DIFFERENT POINTS IN WEIR CHANNEL
COMPARED WITH STANDARD HEAD AT "A"
Scale in Feet
6
5
4
3
2
1
0

Fig. 26.

It is obvious that where the bottom water is retarded there must be a corresponding acceleration of the velocity of the water at higher levels, and as there appears to be no force to cause this acceleration except that of gravity, there must be a lowering of the water surface beginning at a point vertically over the origin of the angle of pressure. The lowering at this point, however, is such a minute quantity that it is not perceptible, and it is only somewhat farther down stream that the beginning of the surface curve can be detected.

As the moving water approaches the weir, it necessarily mounts upward to pass over the crest, and it is natural to think of this process as occurring rather uniformly throughout the whole width of the channel. It is quite likely that this would be the case if the velocities were uniform in all parts of the cross-section, but where there is a higher velocity in one part of the width of the channel than in other parts this uniformity no longer exists.

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Unless precautions are taken to prevent such action, the velocity of the water in the middle of the channel is likely to be greater than that at the sides, and, consequently, a greater pressure is produced within the angle of pressure at the middle of the channel than elsewhere. This condition cannot exist without causing lateral currents within the angle of pressure, and these in turn cause whirling motions which appear to be accelerated by the discharge of the water at the weir opening.

These movements may not only be deduced from theoretical considerations, but they have been observed practically. The speaker once had a small channel and weir constructed with one side of the channel of glass, for the purpose of studying these motions. The principal dimensions of the apparatus were as follows:

Width of channel and length of weir	1 ft.
Height of weir	1 "
Length of channel	8 "

A false bottom was provided by which the depth of the channel could be diminished to 0.50 ft. The motions of the water were made visible by mixing with it partly water-logged saw-dust.

There appeared to be an angle between the face of the weir and the bottom of the channel, extending up stream for about the height of the weir, in which there was no regular flow. The water frequently entered this angle near the middle of the channel, reached a point near the weir, next turned horizontally toward the side of the channel, then moved upward with an accelerating spiral motion, and passed over the weir. At times the motions within this angle were very irregular.

During the experiments on the 19-ft. weir, motions in the angle above the weir, such as were observed with the weir having the glass side, evidently took place. The velocities in the middle of the channel of approach were greater than in other parts of the channel, and it was found that partly water-logged saw-dust discharged through a pipe at the foot of the weir in the middle of the channel did not pass over the central part of the weir, but all of it appeared at the ends. There was evidently a strong spiral movement in this case, as it caused a swelling of the sheet at the ends, and adjoining the swelling there was a depression of nearly equal extent.

It seems to the speaker not improbable that these movements may be an important factor in causing the variation in the results obtained by different experimenters, and that in making experiments in the future and in the application of the results of experiments to practice, special care should be taken to produce a uniform velocity in all parts of the cross-section of the channel of approach, so that these irregular movements which have been described may be minimized.

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The speaker once made experiments—which impressed him deeply—as to the possible effect of these upward spiral movements at the ends of weirs. In these experiments he observed the time required to empty a basin, having a circular horizontal cross-section, through an orifice in its bottom. The first experiment was made when the water in the basin was perfectly still. The plug was removed carefully so as not to set up any motion in the water other than that caused by the discharge through the orifice.

The next experiment was made in the same manner, except that the water, before the removal of the plug, had a slight rotary motion. In this case the time required to empty the basin was just twice as great as in the first experiment, showing a very great difference in the coefficient of discharge of the same orifice as the result of what appeared in the beginning of the second experiment to be a very slight motion of the water above the orifice.

There was no velocity of approach to the orifice at the beginning of either experiment, in the sense that velocity of approach is motion in the direction of the orifice, but the slight rotary motion at the beginning of the second experiment was soon increased by the discharge through the orifice into a violent whirling motion which had a radical effect on the discharge.

This case seems somewhat analogous to that of the weir, except that, in one case, the motion is downward toward the orifice and in the other it is upward. The velocity of the water approaching the weir may be so small as to be practically negligible as an element directly affecting the discharge, and yet, if the velocity in one part of the channel is greater than in another, it may start spiral motions to be augmented by the weir discharge, and thus become practically important.

The speaker believes that the view is prevalent that a very long channel of approach to a weir is a desirable feature, and that in such a case no screens would be required. This does not accord with the views here expressed. Water after flowing a long distance through a straight channel acquires very different velocities in different parts of the cross-section, the maximum velocities being in the middle of the channel and the lower velocities around the margins. Such uneven distribution of velocities, therefore, would set up secondary currents in the angle just above the weir, which are undesirable.

It is desirable, of course, to have a sufficient length of channel above a weir so that minor oscillations above the final screens may be prevented by a raft, and that screens may be provided to produce a uniform velocity throughout the cross-section at some point distant from the weir more than 2½ times its height.

An additional distance to the screens of from 10 to 20 ft. is also advantageous, in order to eliminate the minor boils and whirls resulting

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from the passage of water through a screen, to allow bubbles to come to the surface, and to cause the water to become level from one side of the channel to the other.

Screens should be designed with care, in order to produce the desired results. The coarse screen for equalizing the velocity in all parts of the channel should operate under a sufficient head so that the flow through its different orifices will not be materially affected by irregularities in the velocity of the approaching water. If a screen is made with vertical slats and there is considerable head, the drop of the water at the screen will cause the maximum velocity to be at the bottom of the channel. This should be guarded against, and there are many ways in which it may be done.

A free fall of the surface of the water at a screen should be avoided, in order to prevent the formation of bubbles, and for other reasons. The final screen should be fine, and preferably with diverging openings and little fall.

The place of taking the head needs consideration, the main requirement, when there is a moderate velocity of approach, being that it be taken at a place where it will not be within the angle of pressure. As a rule, there would be no harm, provided the head is measured well above the bottom, in taking it somewhat nearer the weir than the upper end of this angle, say, at a distance from the weir not less than twice its height, but 6 ft. may be assumed as the minimum.

The method of taking the head is much more important. It is very rarely the case that a satisfactory measurement of the head can be made by direct measurement to the surface of the water above the weir, although the elevation of this surface is what is desired. The extended and accurate experiments of Hiram F. Mills, Hon. M. Am. Soc. C. E., on piezometers* show that "with currents flowing parallel with the side of a straight conduit, where the velocity is neither increasing nor diminishing, with orifices having edges in the plane of the side, and with passages normal thereto, the piezometric column will indicate the true height of the surface of the water in the conduit when in motion as well as when at rest." He calls attention to the necessity of attending carefully to these conditions when it is desired to obtain exact results.

The connection from the piezometric opening to the pail where the hook-gauge is placed may be made with a pipe, and, if there are no oscillations in the channel and the pipe is free from air, the water in the hook-gauge pail will stand at the same level as the surface of the water in the channel.

The speaker has tested a piezometer conforming to the requirements thus set forth, and used in connection with experiments on velocity of approach, by comparing the heads obtained with it with those obtained by direct measurement to the surface of the water, and the differences were only from 0 to 0.0003 ft. with low velocities of approach, and from 0.0003 to 0.0004 ft. with high velocities of approach. Mr. Stearns

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* "Experiments upon Piezometers used in Hydraulic Investigations," *Proceedings*, Am. Academy of Arts and Sciences, 1878, p. 52.

If the water in the channel oscillates, the mean height of the water in the hook-gauge pail may be more or less than the average height of that in the channel, unless the connecting pipe and the orifices at both its ends have equal discharging capacity in both directions under a given head. For instance, if the entrance to the pipe from the hook-gauge pail were rounded, and that from the weir channel were square, and the pipe itself had equal resistance to the flow in either direction, the mean level of the water in the hook-gauge pail, as the result of oscillations, would stand lower than the mean level of the water in the channel.

It is probable that, even if the entrances to the pipe from the channel and from the hook-gauge pail are made identical, the mean level of the water in the latter may be different from the mean level of the water in the channel, by reason of the fact that the entrance to the pipe from the pail would be from quiet water, and that from the channel would be from water flowing at right angles to the plane of the orifice.

For the reasons stated, there can be no certainty that a correct measurement of the head will be obtained when there are oscillations in the channel.

Still one other feature needs to be considered: Mills' experiments proved that accurate measurements of the height of water in a channel may be obtained by using piezometers which comply accurately with his requirements when the water is flowing at a constant elevation, so that the pipe leading from the orifice to the gauging basin transmits pressure and does not cause a current through the pipe. If there are oscillations, there is necessarily a discharge into or from the orifice, and there is no evidence that, under these circumstances, the piezometric measurement will be correct. It is not difficult to prevent oscillations or to reduce them to extremely small amounts, except where they are caused by the wind, and the effects of the wind can be avoided by housing the apparatus.

When gaugings are to be made by the hydro-chemical method, it may not be feasible to suppress oscillations without at the same time suppressing the agitation and turbulence that are necessary for the thorough mixing of the salt solution with the water in the channel.

In order that, in the future, results may be produced which are consistent with one another and capable of reproduction at other

Mr. Stearns. weirs, the speaker submits the following as some of the conditions which should be observed:

1.—The weir should be one with end contractions suppressed. This is the general practice at the present time.

2.—A basin should be provided for measuring the water discharged by the weir, as this is the simplest and most accurate method of determining the volume.

3.—The weir channel should have sufficient depth, so that the velocity of approach will at all times be small.

4.—The weir and channel should be covered, and protected from disturbance by the wind.

5.—Arrangements should be made for a uniform flow, free from oscillations.

6.—Minor oscillations should be prevented by a raft above the screens.

7.—Care should be taken to produce an equal velocity in all parts of the weir channel. Current-meter measurements of the velocities in different parts of the channel should be made and recorded, and the screens should be modified until uniformity is attained.

8.—Piezometers should be provided on both sides of the channel, connected with separate hook-gauges. These piezometers should conform with the requirements set forth by Mr. Mills. In the case of very wide channels, one or more additional piezometers may be required in the central portion of the channel.

9.—It is desirable that observations be made of the head in the angle at the foot of the weir, to determine whether the excess of head in this angle is normal; and other tests should be made in order to determine the movements of water in the angle up stream from the weir.

Coming now to a more direct discussion of Mr. Nagler's paper, the speaker appreciates the high degree of skill which has been displayed by the author in obtaining such consistent results in weir measurements by the hydro-chemical method. It is surprising that such uniform results could be obtained where so many different volumetric and chemical determinations were necessary.

Looking at the subject broadly, the speaker believes that, where the most accurate results obtainable are desired in the measurement of water over weirs at the present time, it is best to use a formula based on the results obtained by various experimenters rather than one deduced from any one set of experiments; and as this represents his idea of the most accurate results obtainable with present information, he obviously does not accept new results which for moderate

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heads on the weir are greater than those obtained by any other experimenter.

As has already been stated, the variation in the results obtained by different experimenters appears to be due to the conditions, known and unknown, under which the particular experiments were made, and, judging from the high discharge over the author's weir with moderate heads, the conditions in his case were especially unfavorable.

In order to compare the author's results with others, the speaker has recomputed them, after correcting the depths for the effect of velocity of approach, and in this way has obtained the corresponding coefficients for a weir of infinite height—or, in other words, for a weir in which the velocity of approach is negligible.

This correction has been made, not by applying Bazin's general formula for the discharge over weirs, which is quoted by the author, but by using the formula directly determined by Bazin from his experiments with weirs of different heights. According to this formula the observed head on the weir is corrected for velocity of approach by adding $1\frac{2}{3}$ times the head due to the mean velocity of the water in the weir channel. The coefficient, $1\frac{2}{3}$, is a generalization by Bazin of varying coefficients found with different heights of weirs and different heads on the weirs. Fteley and Stearns, as the result of their experiments on velocity of approach, adopted 1.5 as a general coefficient in the same formula.

After recomputing the results of the author's experiments in the manner indicated, so as to make them comparable with those obtained by others, it is found that with the smaller heads on the weir, ranging from 0.4 to 0.7 ft., his results are somewhat above those of Bazin, which, in turn, are considerably above those of all other experimenters. With a head on the weir of about 1.6 ft., the results agree well with those of Francis, Fteley and Stearns, and Bazin. With heads of about 4 ft. no comparisons can be made, because other experimenters have not dealt with such large heads, but the speaker believes that those experiments with very high heads have little general value, because of the high velocity of the water in the channel of approach.

The effect of velocity of approach on the discharge over weirs has been determined experimentally by causing the same quantity of water to flow over weirs of different heights and noting the effect on the head on the weir. In the extreme case in Bazin's experiments, the maximum effect was 0.144 ft. on a weir 0.80 ft. high; in the extreme case in the Fteley-Stearns experiments, 0.128 ft. on a weir 0.50 ft. high. Using the Bazin formula, the effect of velocity of approach in the author's experiment with maximum head would be 0.377 ft. on a weir 3.72 ft. high.

In most practical cases the difference in the effect of velocity of approach by the formulas of Bazin and of Fteley and Stearns is

Mr. Stearns. unimportant, but, as applied to the maximum experiment of the author, it amounts to a difference of 0.038 ft., which would affect the discharge by about $1\frac{1}{3}$ per cent.

The author suggests that his experiments with large heads verify Bazin's formula for these greater heads, but, even if this were the case for a weir 3.72 ft. high, it would not verify the formula for other heights of weir, unless that part of the formula which takes account of the effect of the velocity of approach is strictly correct, and, because of the arguments above stated, there is no reason to think that any formula for velocity of approach can be depended on so far beyond the limits of actual experiment.

In regard to the coefficients in the weir formula for high heads, it may be said that experiments with orifices and nozzles show that the law that the discharge varies as the square root of the head is applicable to very high heads, and the same principle is involved in the weir formula when the heads are not small and the discharge is not affected by velocity of approach. Hence, one may reasonably, and probably without any serious error, use for a head of 4 ft. the coefficient deduced from experiments with a head of 1.5 ft. The uncertainty in practice arises more from the effect of velocity of approach, and it is the formula for making this correction that is especially important when dealing with high heads in cases where a great depth of channel cannot be obtained.

Attention is again called to Fig. 25, which shows the results obtained by different experimenters, after eliminating the effect of velocity of approach, so that the coefficients are applicable to a channel of infinite depth.

When Francis made his correction for velocity of approach, no trustworthy experiments had been made to determine the amount of such correction, and, consequently, he adopted a correction, based mainly on theoretical considerations, which gave satisfactory results with his experiments, in which the effect of velocity of approach was small.

Since that time, however, experiments by Fteley and Stearns and by Bazin show definitely that velocity of approach has greater effect than is indicated by the Francis formula. His experiments, therefore, have been recomputed, with larger corrections for velocity of approach than he used, and the diagram is based on the corrected results. The curve representing the mean result of his experiments as recomputed, was determined by the formula, $Q = 3.313\ L\ H^{\frac{3}{2}} + 0.006\ L$. This is a substitute for the Francis formula for suppressed weirs, which, for a channel of infinite depth, is $Q = 3.33\ L\ H^{\frac{3}{2}}$.

When the latter formula is used, the correction for velocity of approach should be that given by Francis, which is substantially an addition to the measured head on the weir of the head due to the mean velocity of the water in the channel of approach; but, if the revised formula is used, the addition to the measured head should be substantially 50% greater.

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The curve representing the Fteley and Stearns experiments on the 5-ft. weir was computed from the formula, $Q = 3.33\ L\ H^{\frac{3}{2}} + 0.0065\ L$; that representing their experiments on the 19-ft. weir from the formula, $Q = 3.291\ L\ H^{\frac{3}{2}} + 0.004\ L$.

The Rehbock formula for a channel of infinite depth is

$$Q = \left(3.235 + \frac{0.0167}{H - 0.0094}\right) L\ H^{\frac{3}{2}}.$$

The curve representing Bazin's experiments is his experimental curve, and not one computed from his formula, which does not agree as well with his experiments.

The Nagler curve is one representing his experiments after they have been corrected for velocity of approach.

It is not the speaker's purpose in this discussion to pass on the merits of the different series of experiments, but it does not seem out of place to call attention to a prominent feature of the diagram, namely, that the experiments of Francis, Fteley and Stearns, and Rehbock, with the larger heads on the weir—say, those above 1 ft.—give coefficients which change very little with increasing heads. In this respect, they seem to be in harmony with the well-established principle, already referred to, that velocities vary as the square root of the head, except when the heads are small. With small heads and the consequent low velocities, such factors as the cohesion and viscosity of the water and its adhesion to the edge of the weir have a very much more important effect on the discharge than with large heads and high velocities.

Bazin's experiments, on the other hand, show rapidly decreasing coefficients as the heads increase, and, even with the larger heads on the weir, this marked decrease in the size of the coefficient continues.

Francis made a series of weir experiments at the Tremont turbine,* entirely separate from those on which his formula for the discharge over weirs was based, in which a constant volume of water was discharged over weirs of different lengths, and these experiments may be used to test the rate at which coefficients increase with decreasing heads on the weir.

These experiments were made with weirs having end contractions, and the conditions for maintaining an exactly constant volume of water over the weirs were not very favorable, as there was a somewhat variable head acting on the orifices through which the water was

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* "Lowell Hydraulic Experiments," p. 88.

Mr. Stearns. discharged; but the experiments were conducted with much care, and due account was taken of the variations in the head on the orifices.

By selecting only the experiments in which the discharge was least influenced by end contractions, results may be obtained which, though not conclusive, will indicate whether or not, within the range of the experiments, the experimental formula or curve tested gives coefficients increasing too much or too little with decreasing heads on the weir. Corrections for end contractions were made by using the rule subsequently adopted by Francis, namely, the reduction of the measured length of the weir by one-tenth of the head on it for each end contraction.

As the volume of water in these experiments was practically constant, the head on the shorter weir is obviously greater than that on the longer weir. If, therefore, one assumes the coefficient for the head on the shorter weir to be that given by any particular weir formula or curve, he may compute the corresponding coefficient for the smaller head on the longer weir. If this coefficient is larger than the coefficient for the smaller head, as deduced from the weir formula or curve under consideration, it furnishes an indication that the coefficients in the formula or curve do not increase fast enough, and, if the coefficient is smaller, the indication is reversed.

The weir formulas or curves which may well be compared, because the experiments on which they are based conform most nearly to the range of heads in the Francis experiments at the Tremont turbine, are those of Fteley and Stearns for the 5-ft. weir, Bazin, and Rehbock.

By referring to Column 13 of Table 6 it will be seen that the differences of the experimental coefficient for the smaller heads from that by formula or curve are always plus in the case of the Fteley and Stearns formula for the 5-ft. weir, and practically the same statement may be made as to the differences in the case of the Rehbock formula. On the other hand, the differences in the case of the Bazin experimental curve are always minus. The average difference in the case of the Rehbock formula is + 0.34 of 1%, Fteley and Stearns formula, + 0.44 of 1%, and the Bazin experimental curve, — 1.11 per cent. In other words, the coefficients in the Rehbock and Fteley and Stearns formulas do not increase quite as rapidly with decreasing depths on the weir as is indicated by these experiments, and in the case of the Bazin experimental curve they increase more rapidly.

There are in this paper, and especially in the introductory portion, statements of a historical nature which are inaccurate. Thus, the author speaks of the experiments of Francis as covering a range in head on the weir of from 0.736 to 1.060 ft., whereas these experiments covered a range of from 0.592 to 1.569 ft.

In the next paragraph, referring to several experimenters, he says that they were unable to use higher heads, due to the fact that their

TABLE 6.—WEIR FORMULAS AND CURVES, TESTED BY THE FRANCIS WEIR EXPERIMENTS MADE AT TREMONT TURBINE.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	FTELEY AND STEARNS FORMULA FOR 5-FOOT WEIR.											
	Shorter Weir.					Longer Weir.						
No. of series.	Head on weir, in feet.	Length of weir, in feet.	No. of end contractions.	Length, corrected for end contractions, in feet.	Coefficient by F. & S. formula.	Head on weir, in feet.	Length of weir, in feet.	No. of end contractions.	Length, corrected for end contractions, in feet.	Coefficient by F. & S. formula.	Coefficient from Francis' experiments.	Difference, experimental coefficient from that in Column 11. Per cent.
VII........	1.1333	5.487	2	5.260	3.3354	0.5929	13.978	4	13.741	3.3442	3.3741	+ 0.89
VII........	0.9553	6.987	2	6.796	3.3370	0.5184	16.980	4	16.773	3.3474	3.3823	+ 1.04
IV........	0.6554	6.987	2	6.856	3.3423	0.3584	16.980	4	16.837	3.3603	3.3656	+ 0.16
III.	0.4715	6.989	4	6.800	3.3495	0.2917	13.978	4	13.861	3.3713	3.3769	+ 0.17
III........	0.4681	6.987	2	6.893	3.3503	0.2552	16.980	4	16.878	3.3804	3.3991	+ 0.55
II.........	0.3745	6.987	2	6.912	3.3584	0.2339	13.978	4	13.884	3.3874	3.3873	0
VIII......	0.4936	5.487	2	5.388	3.3488	0.2282	16.980	4	16.890	3.3896	3.3984	+ 0.26
Average..	0.6502					0.3541						+ 0.44

(Note: All columns omitted are the same as those above.)

(1)	(6)	(11)	(12)	(13)	(6)	(11)	(12)	(13)
	BAZIN EXPERIMENTAL CURVE.				REHBOCK FORMULA.			
No. of series.	Coefficient from Bazin curve.	Coefficient from Bazin curve.	Coefficient from Francis' experiments.	Difference, Column 12 from Column 11. Per cent.	Coefficient by Rehbock formula.	Coefficient by Rehbock formula.	Coefficient from Francis' experiments.	Difference, Column 12 from Column 11. Per cent.
VII..........	3.3354	3.3909	3.3741	— 0.50	3.2499	3.2636	3.2876	+ 0.73
VII..........	3.3488	3.4060	3.3942	— 0.35	3.2527	3.2678	3.2968	+ 0.89
IV...........	3.3804	3.4540	3.4039	— 1.45	3.2609	3.2829	3.2836	+ 0.02
III	3.4171	3.4860	3.4450	— 1.18	3.2711	3.2942	3.2978	+ 0.11
III...........	3.4185	3.5100	3.4682	— 1.19	3.2714	3.3030	3.3190	+ 0.48
II............	3.4599	3.5265	3.4897	— 1.04	3.2807	3.3094	3.3089	— 0.02
VIII.........	3.4120	3.5350	3.4626	— 2.05	3.2695	3.3114	3.3179	+ 0.20
Average.....				— 1.11				+ 0.34

Mr. Stearns. volumetric measuring basins filled too rapidly with the large quantity of water which flowed over the weir at high heads. The Fteley and Stearns experiments were included in this statement. There was no such limitation in the experiments with the 19-ft. weir. With the maximum discharge, the basin filled in about 36 min., it may be noted that the author discharged his volumetric tank containing the salt solution in about 15 min.

In the same paragraph he adds: "Nevertheless, these few experiments, within so small a range in head, were used by each experimenter in evaluating the coefficients for the standard weir formulas which bear their names." This statement is somewhat incorrect, because the Fteley and Stearns general weir formula, where it relates to heads of more than 0.5 ft., was based almost wholly on the experiments by Francis. However, the formula was given a form which would make it agree with these results of Francis and with those obtained by Fteley and Stearns with small heads on the weir, thus making a formula of more general application than that of Francis, which was not applicable to small heads on the weir.

The author seems to suggest in his statement that a few experiments are not a sufficient basis for a formula, but this depends on the accuracy of such experiments. A reference to those on the 19-ft. weir by Fteley and Stearns, as represented by Fig. 25, shows clearly that the line representing them is practically as well determined by the number of experiments made as if they were multiplied many times.

He states, on page 52,* that the points at which the gauges which he used tapped the flume duplicated the experimental points of observation used by Bazin, Fteley and Stearns, and Francis. Hence, his experiments seem to indicate that the discrepancies between the Bazin, Francis, and Fteley and Stearns formulas cannot be accounted for by the different points of observation used in their experiments.

In order to duplicate the Fteley and Stearns points of observation, he connected the stilling tank to the side of the channel 6 ft. from the weir, and 0.414 ft. below the weir crest. In the experiments on the 5-ft. weir of Fteley and Stearns, the head was taken about 1 ft. above the bottom of the channel, 6 ft. up stream from the weir, at a point in the channel 1.5 ft. from its side. In the experiments on the 19-ft. weir of Fteley and Stearns, the heads were taken through four double piezometers, each in the middle of a fourth part of the width of the channel, just below the level of the crest of the weir.

To represent the point of observation used by Francis in experiments on suppressed weirs, the author connected the stilling tank with the side of the flume at a point 6 ft. from the weir and 3.22 ft.

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* *Proceedings*, Am. Soc. C. E., January, 1918.

Mr. Stearns.

below the crest. Francis took his observations in the middle of the channel at a point 6 ft. from the weir and 4.80 ft. below the crest. The difference in this case is important, because the head as taken by the author was probably outside the angle of increased pressure, and the head taken by Francis was within the angle of pressure, but not where the increased pressure was great. This was demonstrated in the case of the Francis experiments, because he found by test that the head at the point chosen, 6 ft. from the weir, was greater than the head 12 ft. from the weir. In the Francis experiments, however, the velocities were so low that the point of taking the head did not have much importance.

The author is rather optimistic about a number of features connected with the experiments. Thus, on page 52,* in discussing the method of taking the head on the weir, he says: "Certainly the fact that the conducting pipe and tapping hole were 2 in. in diameter eliminated all error as to the nature of the tap." It would be rather interesting to know why the use of a pipe and tapping hole of a given diameter should eliminate error. He gives no information as to whether the taps complied with those features which Mills, from his experiments on piezometers, found necessary, namely, as to whether the orifice was precisely in the plane of the side of the flume, and whether the pipe was precisely normal thereto.

He says elsewhere in the paper that when the water in the flume had a velocity exceeding 3.3 ft. per sec. "the waves * * * were of so great a magnitude that the floating railroad ties were ineffective in decreasing the amplitude of their motions." With such oscillations, it would seem quite possible, for reasons already suggested, to record a head at the hook-gauges which was not the true head on the weir, notwithstanding what he refers to as "the remarkable agreement between the mean readings for all three hook-gauges and the piezometer tube."

The author speaks in one place of the excellent velocity distribution in most experiments, and, on page 23,* presents velocity contours at a point 25 ft. above the weir, which show something far different from a uniform distribution, as the velocities range from less than 1 ft. per sec. near the surface to 3.2 ft. per sec. at mid-depth. The low velocity at the surface may have been due to the floating railroad ties a short distance above this section, and the conditions nearer the weir may have been more favorable.

On page 16,* the statement is made that placing the weir at the end of the flume gave it a free basin about 90 ft. in length, which does not seem to agree with the statement that there were two floating railroad ties placed across the flume about 28 ft. above the weir.

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* *Proceedings,* Am. Soc. C. E., January, 1918.

Mr. Stearns. It is rather interesting to note the optimistic conclusions of the experimenters who have obtained especially low and high results. Thus, Rehbock, who experimented with heads on the weir ranging from 0.03 to 0.59 ft., referring to the degree of accuracy of his formula, stated that he was convinced that the results to be obtained by it deviated not more than ½ of 1% from the true value.

The author, with results that are about 4.5% higher than those obtained by Rehbock, says: "There is no doubt that some experiments give the correct discharge within 0.1 of 1 per cent. In general, it might be said that the maximum variation from the true discharge is less than 0.6 of 1% for every experiment except No. 20."

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications.

THE ECONOMICS OF STEEL ARCH BRIDGES

Discussion.*

By Paul A. Blackwell, Assoc. M. Am. Soc. C. E.

Mr. Blackwell.

Paul A. Blackwell,† Assoc. M. Am. Soc. C. E. (by letter).‡—The author has again enriched engineering literature by his latest contribution, "The Economics of Steel Arch Bridges." Any one who has had to do with arch work knows the difficulty of getting working data from the mass of mathematical information on this subject. This has resulted in the decision of the average engineer to steer clear of arches of all descriptions, because they are difficult to calculate; and, that there ever were any economical considerations applying to structures of this type, probably never entered his mind.

It is true that arches are generally built as monuments, or for advertising purposes, and are chosen for these purposes because they are easily adapted to esthetic treatment; and, in view of their use only as monuments, the question of economy has hardly been considered.

Several years ago the writer, having in view something of what the author has brought out, endeavored to make a comparison between the economical advantages of the generally accepted three types of arch. Reducing the results that were found to the same classification as given in this paper, the writer will comment as follows:

First.—In reference to the economic ratio of rise to span, it seems to be the consensus of opinion that the correct ratio is about 1:5. This agrees with the ratios given, although this, like everything else that has to do with bridge work, must depend on what can be done,

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* This discussion (of the paper by J. A. L. Waddell, M. Am. Soc. C. E., published in March, 1918, *Proceedings*, and presented at the meeting of May 1st, 1918), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Roanoke, Va.

‡ Received by the Secretary, April 8th, 1918.

Mr. Blackwell. and not always what should be done; and, of course, as the type of arch chosen must be the best suited for the place, the ratio of rise to span is not dependent on the type.

Second.—The writer takes exception to the following statement: "As far as solid-rib arches are concerned, the question of the economic depth of the rib does not arise." As so many things enter into the problem—one of which is shipping—the available depth is often determined. This may not be the theoretical economical, or least-weight, depth; but, when ease of manufacture, obtaining material, and ease of erection are considered in their relative importance as economical factors, the limit of the solid-web arch is reached with about a 10-ft. web, which would correspond to a probable maximum span of 400 ft. In nearly all existing arches the general practice has been to make the depth of ribs about one-twenty-fifth to one-fiftieth of the span. The writer generally uses one-fortieth, about one-third of what the author finds as the economical depth. A depth of 60 ft. for an 800-ft. arch rib would require members of the webbing about 80 ft. long. These members carry comparatively small stresses, and, in order to be so long, would have to be very large to have sufficient stiffness, and would probably be as large as the chords themselves. This would not be economical; besides, the appearance of the arch is improved by reducing the depth of the web. Varying the shape of the hingeless arch (widest at the ends) adds to the appearance and results in economy of material.

Third.—The writer does not believe that there is any economy in putting the crown-hinge in the top chord. Generally, a neater detail, and a more easily erected and better looking structure results from placing the crown-hinge in the bottom chord (for spandrel-braced arches). In all other cases the crown-hinge should be placed as the author recommends.

Fourth.—The writer believes the spandrel-braced two-hinged arch, of moderate span, to be the most satisfactory structure for railway traffic, when an arch is necessary or desired; but, for highway structures, should the condition allow, an arch-rib structure is better.

Fifth.—The writer has found that the three-hinged arch is the heaviest type; the two-hinged and hingeless are of about the same weight. The hingeless arch is the stiffest, but, in order to make the ends truly fixed, there is no economy in weight over the two-hinged arch.

Sixth.—The accepted modern method is to calculate the arch as three-hinged for dead load and erection, and then rivet up in the field, making it two-hinged for live load and temperature. It relieves the arch of much secondary stress, and causes the joints to come to their bearing. It is much the better way.

Seventh.—The arch with cantilever spans makes a pleasing structure. The economy, however, is questionable, considering the lack of

Mr. Blackwell.

rigidity of all cantilevers, and the reduction in the weight of the arch proper is slight; most of the saving in weight is due to the change of length of the side spans. It is always more economical to carry loads in tension or compression than in bending.

Eighth.—The field of the arch, for purely economical reasons, lies somewhere between 500 and 1 000 ft. The writer's experience in this line has been with small arches (250 ft.) which weigh practically the same as a simple span of the same length.

In conclusion, the writer fully realizes the vast amount of labor involved in getting these results, and the author is to be congratulated on the orderly manner in which he has presented his findings.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

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DISCUSSION ON FINAL REPORT OF THE SPECIAL COMMITTEE ON MATERIALS FOR ROAD CONSTRUCTION AND ON STANDARDS FOR THEIR TEST AND USE*

BY J. O. PRESTON, JUN. AM. SOC. C. E.

J. O. PRESTON,† JUN. AM. SOC. C. E. (by letter).‡—The Committee, on page 2329,§ invites information on the subject of "proper methods of sampling highway materials." This work is usually done in the field by inspectors who may or may not have written laboratory instructions. The instructions usually convey to the inspector a notion of the need for an average sample. It has been the writer's experience that the "average" notion is much overworked. Mr. Preston.

Materials that vary between extreme limits over the work are said to average well. This is especially true with concrete materials. As a result, in many cases the variations in density of adjoining batches of concrete cause cracking, due to irregularities in the grading of the sand and stone, and the consequent widely varying coefficient of expansion. A composite sample of an aggregate from even a small area rarely indicates the actual conditions. If the average is uniform throughout the work, or if all the materials vary but slightly from the average, such a sample would be a fair specimen. In practice, however, this is seldom the case.

Experience has proved the inadequacy of leaving to field inspectors the determination of the quality of materials. For the same reason, it is inadvisable that the selection of samples from varying grades of materials, such as sand and stone, be left to the average inspector's

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* Continued from February, 1918, *Proceedings.*

† Rochester, N. Y.

‡ Received by the Secretary, April 9th, 1918.

§ *Proceedings,* Am. Soc. C. E., December, 1917.

Mr. Preston. "eye". The only safe procedure is to have trained men in the laboratory for the purpose of going into the field and collecting all samples.

It is believed that it will prove ultimate economy for State or municipal laboratories (and all other large-scale organizations), if instead of awaiting samples to be sent in for test, they develop an organization to collect them. This organization would prove of great value in many other ways; not only would laboratory control be more complete, but field inspectors could be instructed in the proper use of materials. (Engineers seldom have time for sufficient instruction in the field.) The slight additional cost would be cheap insurance; it would aid both the engineer and the contractor to obtain better materials and prevent their misuse or adulteration.

MEMOIRS OF DECEASED MEMBERS

Note.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

HIRAM MARTIN CHITTENDEN, M. Am. Soc. C. E.*

Died October 9th, 1917.

Hiram Martin Chittenden, the son of William F. and Mary Jane (Wheeler) Chittenden, was born at Yorkshire, N. Y., on October 25th, 1858. He was graduated from the United States Military Academy at West Point, N. Y., in 1884 and assigned to the Corps of Engineers.

After three years at the Engineer School of Application at Willetts Point, Lieut. Chittenden was graduated and sent to Omaha, Nebr., as Engineer Officer of the Department of the Platte. He held this appointment for two years, during which time he prepared a topographical map embracing Colorado, Wyoming, and Utah, and portions of the surrounding States.

In 1889, he was assigned by the War Department to take charge of the improvement of the Missouri River above Sioux City, Iowa, where he remained until 1891, when he was given charge of improvement work in Yellowstone National Park. He carried on this work until 1893, when he was assigned to duty on the Louisville and Portland Canal.

In the fall of 1894, Capt. Chittenden was made Executive Officer of the Board of Engineers and had charge of a canal survey between Lake Erie and the Ohio River. This assignment was terminated in 1896, when he was made Secretary of the Missouri River Commission, in personal charge of the improvement of the Osage and Gasconade Rivers in Missouri and the surveys on the Missouri River, as well as surveys for reservoir sites in Wyoming and Colorado.

When war with Spain was declared in 1898, Capt. Chittenden was appointed Chief Engineer of the Fourth Army Corps, with the rank of Lieutenant-Colonel of Volunteers. In this position he had charge of the purchase of engineering supplies, the laying out of camp grounds, supplying them with water, etc. While encamped at Huntsville, Ala., he took charge of the municipal improvement of the Huntsville Spring and the erection of the new water-works plant.

At the close of the Spanish-American War, Capt. Chittenden was made Secretary and Disbursing Officer of the Missouri River Commission, in charge of the improvement of the Missouri River from Sioux City to its source, of the Osage and Gasconade Rivers, and of

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* Memoir prepared by the Secretary from information on file at the Headquarters of the Society.

Yellowstone Park, with headquarters at Sioux City, Iowa. It was while on this work that he laid out the wonderful roads of Yellowstone Park and wrote a very interesting book* describing the Park itself.

In 1904 he was promoted to the rank of Major and transferred to Seattle, Wash., in charge of the United States Engineer Office and work in that district. His most important work while in this position was the planning of the Lake Washington Canal, a project then being agitated by the citizens of Seattle. A plan had already been made for this Canal, which included two locks, at an estimated cost of about $7 000 000, which was prohibitive. After some study of the question, Maj. Chittenden submitted a plan with only one lock and at a cost which enabled the project to be carried out. The Lake Washington Canal is a ship canal about 7 miles long, connecting Puget Sound with Lake Washington and outside of the Panama Canal is said to be one of the most important canals built by the Government, the lock being second in size only to those at Panama. He also served as a member of the Federal Commission on the Yosemite National Park in 1904, and on a commission of engineers appointed to investigate the question of the Sacramento Flood Control.

In 1908, Maj. Chittenden was promoted to the rank of Lieutenant-Colonel and in 1910 he was made a Brigadier-General, but was retired shortly afterward owing to partial paralysis, brought on by shock sustained by a long test ride which, with all Army Officers, he was compelled to take at that time.

After his retirement, Gen. Chittenden devoted himself to consulting engineering work and investigations. On September 5th, 1911, he was elected a member of the Port Commission and was made the first President of the Port of Seattle, which position he held until October 15th, 1915. This Commission had been organized under the laws of the State of Washington, to take up the question of a harbor for Seattle; Gen. Chittenden devoted himself to this work and by his commanding personality gained the respect of those associated with him to such an extent that the project was carried out and the Port of Seattle, with its dock and terminal facilities, was built at an expenditure of about $6 500 000. The traffic through this port to Siberia has been so enormous during the last two or three years that the docks have been found to be too small, thus vindicating Gen. Chittenden's judgment.

His project for a 30-mile tunnel through the Cascade Mountains†, although never constructed, was widely discussed, and his articles thereon were translated and published in both Spanish and French technical periodicals. He was also greatly interested in flood-control work, to the study and literature of which he had devoted much time.

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* "Yellowstone National Park, Historical and Descriptive."

† *Engineering News,* November 16th, 1916, p. 928.

In this connection he was retained in a consulting capacity by the Spring Valley Water Company of San Francisco, Cal., in 1912, and also by The Miami Conservancy District, to report on that project. He visited Dayton, Ohio, on several occasions during 1914-15, and being unable to walk, he was taken to all sites of the work by automobile, most of his research work being done in his rooms; in this manner he made a detailed study of the entire project. Notwithstanding his disability, Gen. Chittenden had an enormous capacity for hard work, and his mind was exceedingly active. It is said of him that when engaged on a project, he could keep many men busy supplying him with information and data in connection with it and that he himself could work steadily from 8 to 12 hours a day for 7 days in the week.

He devoted much of his time to writing, and besides being a frequent contributor to the publications of this Society, he published many articles, especially on waterways, flood control, and water supply, in various technical periodicals. Among his papers before this Society were the following: "Reservoir System of the Great Lakes of the St. Lawrence Basin";* "Forests and Reservoirs in Their Relation to Stream Flow, with Particular Reference to Navigable Rivers";† and "Ports of the Pacific".‡ His last paper, "Detention Reservoirs with Spillway Outlets as an Agency in Flood Control",§ was presented before the Society shortly after his death, at the meeting of October 17th, 1917. He had also discussed various papers presented by other engineers.

Most of Gen. Chittenden's life was spent in the routine engineering work of the Army Corps, in charge of public works in various parts of the United States. His fine personal qualities and his fair treatment of the men under him and the public whom he served, had won for him the respect and admiration of every one who knew him, particularly in the Northwest, where he had spent many of his latter years. An invalid for many years and confined to a wheel chair during the last year of his life, he had developed the human side of his character until his personality affected for good all who came under his influence and made him an honor to the Army and to his Profession.

In a tribute to him, and in appreciation of his qualities as a man and as an engineer, before the Society at its meeting of October 17th, 1917, Charles Evan Fowler, M. Am. Soc. C. E., said, among other things:

"I found him to be the most fair and one of the finest men to work under whom I have ever known * * *. That whether it pleases engineers or not to realize it, their work is for posterity. Gen. Chittenden has not lived to see the flood control work carried out; he has not lived to see his tunnel built; but posterity will, without doubt, thank him for what he has done."

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* *Transactions,* Am. Soc. C. E., Vol. XL, p. 355.

† *Transactions,* Am. Soc. C. E., Vol. LXII, p. 245.

‡ *Transactions,* Am. Soc. C. E., Vol. LXXVI, p. 155.

§ *Proceedings,* Am. Soc. C. E., September, 1917.

He is survived by his widow, who was Miss Nettie M. Parker, of Arcade, N. Y., whom he married on December 30th, 1884, and by two sons, Lieut. Hiram M. Chittenden, Jr., 14th Field Artillery, U. S. A., and Theodore Chittenden, and a daughter, Mrs. J. B. Cress.

Gen. Chittenden was elected a Member of the American Society of Civil Engineers on February 7th, 1900.

OLIVER ZELL HOWARD, M. Am. Soc. C. E.*

Died December 20th, 1917.

Oliver Zell Howard was born in Raleigh, N. C., on December 6th, 1876. He was graduated from Lehigh University in the Class of 1897, with the degree of M. E.

Immediately after his graduation in June, 1897, Mr. Howard was appointed Draftsman in the Engineering Department of the Newport News (Va.) Shipbuilding and Dry Dock Company, where he remained until January, 1900, at which time he became Draftsman for the Baltimore (Md.) Copper Smelting and Refining Company, in charge of rolling mill construction and repair.

From November, 1900, to August, 1901, Mr. Howard was engaged as Draftsman in the Marine Department of the Maryland Steel Company, at Sparrows Point, Md., on the design of traveling towers for ship construction.

From August, 1901, to April, 1902, he was connected with the Bureau of Construction and Repair of the United States Navy Department, as Draftsman in charge of the design of auxiliary machinery, but resigned that position to become Instructor in the Department of Marine Engineering and Naval Construction, at the United States Naval Academy, at Annapolis, Md. He also had charge of the general layout, the preparation of the specifications, and the installation of the mechanical and electrical equipment of the new Marine Engineering Building at the Academy, and assisted the officer in charge of the Department in preparing textbooks on marine engines and machinery and on the mechanical processes pertaining thereto for use at the Academy.

From August, 1906, to February, 1912, Mr. Howard was engaged as Mechanical Engineer and Civilian Assistant to the Head of the United States Naval Engineering Experiment Station at Annapolis,

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* Memoir prepared by the Secretary from information on file at the Headquarters of the Society.

Md., and had charge of the design, inspection, and installation of the mechanical and electrical equipment during the construction of the station buildings, having charge, after their completion, of all the electrical and mechanical tests conducted at the Station.

In February, 1912, he was appointed Assistant Chief Engineer of The Griscom-Russell Company, of New York City, which position he retained until March, 1914. During this time he designed and built garbage disposal plants for Halifax, N. S., and Berkeley, Cal., and a refuse disposal plant for Pittsburgh, Pa., etc.

In March, 1914, he established himself in private practice, as a Consulting Engineer with an office in New York City. Among other work he designed and constructed a chemical plant for the Diamond Match Company, at Wilmington, Cal., as well as a chemical plant for the manufacture of potash for the Salt Lake Chemical Company, at Burmester, Utah.

Early in 1917, Mr. Howard was employed as Supervising Engineer by the Diamond Match Company, with headquarters in New York City, which position he retained until his death on December 20th, 1917.

He was a member of the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, and the Society of Naval Architects and Marine Engineers.

Mr. Howard was elected an Associate Member of the American Society of Civil Engineers on February 28th, 1911, and a Member on May 15th, 1917.

JESSE LOWE, M. Am. Soc. C. E.*

Died April 17th, 1918.

Jesse Lowe was born at Omaha, Nebr., on January 7th, 1861. He attended private and public schools there, later, going to Maryland Agricultural College, a military academy; then to Williston Seminary, at Easthampton, Mass.; and, finally, to Rensselaer Polytechnic Institute, at Troy, N. Y., from which he was graduated in 1885, with the degree of Civil Engineer.

After his graduation Mr. Lowe was, for a short time, Assistant to the City Engineer of Omaha, and Assistant Engineer in locating the Omaha Belt Line Railway, and in the preliminary and location surveys of the Missouri Pacific Railroad west of Omaha. In 1886, he was employed, at Lincoln, Nebr., as Resident Engineer of the Missouri Pacific Railroad.

He went next to Birmingham, Ala., as Assistant Manager of the Birmingham Bridge and Bolt Works. In 1887, he formed a partnership, at Omaha, with the late Andrew Rosewater, M. Am. Soc. C. E., and George B. Christie, M. Am. Soc. C. E., and was extensively engaged in civil engineering work in the Middle West. The following year this firm was dissolved, and that of Christie and Lowe, Civil Engineers and Contractors, was organized and continued until 1913. Mr. Lowe was always an active member of the firm, which was engaged in important engineering works in many parts of the United States, among which were the following:

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* Memoir prepared by George B. Christie, M. Am. Soc. C. E., and Jesse Lowe, Jr., Jun. Am. Soc. C. E.

The Cable Street Railways at Denver, Colo., in 1889; the cable lines of the Cleveland Street Railway Company, at Cleveland, Ohio, and the street railways of the Judson Pneumatic Railway Company, at Washington, D. C., in 1890; the Montague Street Cable Railway, at Brooklyn, N. Y., in 1891; the completion of the cable system at Denver in 1892-93; the piers for the Bellefontaine Bluffs Bridge over the Missouri River and the Harlem Creek Culvert, in St. Louis, Mo., for the Kansas and Northwestern Railroad, in 1892; the Fullerton Avenue Loop, in Chicago, in 1892, the first underground trolley line in America; and the V Street Railway, in Washington, D. C., which was the first in that city. The success of this last piece of work revolutionized street railway construction, and was the pioneer engineering work in doing away with overhead electric wires and placing them underground.

In 1894-95-96, two miles of the Chicago Drainage Canal and the Controlling Works were constructed by the firm, including the great bear-trap dam which regulates the flow of water from the Great Lakes to the Gulf. This contract was awarded on merit for the best design submitted for the regulation of the flow of water through the canal.

In 1897, the firm did railroad and bridge work for the Illinois Central and Louisville and Nashville Railways; levee construction on the Illinois River; and, in 1899, bridge foundations at South Chicago for the Baltimore and Ohio Railroad.

From 1898 to 1913, the firm was engaged in river and harbor improvement for the United States Government, and completed, in order, the jetties at Sabine Pass, Texas, at Calcasieu Pass, Louisiana, and at the mouth of the St. Marys River, Cumberland Sound, Fernandina, Fla.; locks and dams on the Warrior River, Alabama; jetties and improvement of South West Pass of the Mississippi River, Louisiana; closing of Pass á l'Outre and Cubits Gap, Mississippi River, Louisiana; and sea walls at Fort Morgan, and Fort Gaines, Mobile Bay, Alabama.

Mr. Lowe was always an ardent advocate, and a valiant champion, of the Lakes-to-the-Gulf Deep Waterway project, both as to its beneficial bearing on the vast acreage of adjoining valley lands and for the improvement of the transportation facilities from the Lake territory to the Gulf ports.

During his later years he was actively engaged in drainage and reclamation work on the Illinois River and in improving and managing extensive land holdings at Beardstown, Ill.

Mr. Lowe's sudden death, on April 17th, 1918, at Chicago, Ill., came as a great shock to his many friends. He leaves behind him, from coast to coast, a series of monuments which, for ages to come, will testify to his great ability and success as a civil engineer and builder.

He was a member of the Chi Phi Fraternity, Western Society of Engineers, Illinois Society of Engineers, Louisiana Society of Engineers, and the Structural Engineers Association of Illinois.

Mr. Lowe was elected a Member of the American Society of Civil Engineers on October 2d, 1895.

JOHN DASH VAN BUREN, M. Am. Soc. C. E.*

Died March 11th, 1918.

John Dash Van Buren, the son of John Dash and Elvira (Aymar) Van Buren, was born in New York City, on August 8th, 1838. He studied Civil Engineering at Lawrence Scientific School of Harvard University and Rensselaer Polytechnic Institute, Troy, N. Y., and was graduated from the latter in 1860, with the degree of Civil Engineer.

Mr. Van Buren began engineering work under the late Alfred Wingate Craven, Past-President, Am. Soc. C. E., then Chief Engineer of the Croton Aqueduct Department, but resigned when the Civil War broke out in 1861 to enter the Navy as an Assistant Engineer with the rank of Lieutenant. As such, he served with the Gulf Squadron in the James River Campaign and in the Flying Squadron under Commander Wilkes. He was also with the squadron which formed part of the forces under Gen. McClellan in the battle of Malvern Hill.

Following this, Mr. Van Buren was detailed for special duty as Assistant Professor of Natural Philosophy and Engineering at the United States Naval Academy where he served for four years. During the next two years he was detailed as Assistant to Commander Isherwood, at the Bureau of Engineering of the Navy Department. In 1865, he was promoted to be First Assistant Engineer, serving as such until 1868 when he resigned his commission and returned to civil life.

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* Memoir prepared by the Secretary from information furnished by Robert Van Buren, M. Am. Soc. C. E., and on file at the Headquarters of the Society.

In 1869, Mr. Van Buren was admitted to the bar of New York City. He practiced law only a short time, however, and gave it up to return to his former profession as a Civil Engineer.

From 1870 to 1875, he served as Assistant to Generals McClellan and Graham in the Department of Docks of New York City, having been engaged on the reconstruction of the water front.

In 1875, Mr. Van Buren was appointed by Governor Tilden as a member of a commission to investigate the canals of New York State. As a result of his work on this Commission, he was elected to the office of State Engineer and Surveyor, serving in that capacity from 1876 to 1878, during which time many important reforms were carried out in that Department.

On the expiration of his term of office as State Engineer, Mr. Van Buren again took up the private practice of engineering, and made his home at Newburgh, N. Y., where he was employed on the extension of the water-works. As a Consulting Engineer he was engaged on many important engineering works until his retirement from active life several years ago. For a number of years he had made his home at New Brighton, Staten Island, where his death occurred on March 11th, 1918.

Mr. Van Buren was a gentleman of the old school. He had lived a quiet retired life, but was a very congenial companion, and stood high as an Engineer, having been considered one of the best mathematicians in the Profession.

He was a frequent contributor to the technical press and to the publications of the Society, having written papers on "Quay and Other Retaining Walls",* "The Improvement of the Water Front of the City of New York",† and "Notes on High Masonry Dams",‡ as well as discussions on papers by other members.

Mr. Van Buren was married on November 24th, 1875, to Miss Elizabeth Ludlow Jones, of New York City. They had two sons, one of whom died several years ago; the other is now serving in an Engineer Regiment with the American Expeditionary Forces.

He was a Democrat in politics, and was a member of the Loyal Legion, American Geographical Society, Society of Naval Engineers, Society of Naval Architects and Marine Engineers, the Holland Society, and the St. Nicholas Society.

Mr. Van Buren was elected a Member of the American Society of Civil Engineers on May 20th, 1868.

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* *Transactions*, Am. Soc. C. E., Vol. II (1873), p. 193.

† *Transactions*, Am. Soc. C. E., Vol. III (1874), p. 172.

‡ *Transactions*, Am. Soc. C. E., Vol. XXXIV (1895), p. 493.

CLARENCE BROWNING VORCE, M. Am. Soc. C. E.*

Died February 4th, 1918.

Clarence Browning Vorce was born on June 23d, 1866, in New York City, but during his boyhood lived at Farmington, Conn. He received his technical education at the Massachusetts Institute of Technology, from which he was graduated in 1888, receiving the degree of Bachelor of Science.

In July, 1889, he joined the Lake Shore and Michigan Southern Railroad and remained with that Company until February, 1893, holding successively the positions of Transitman, Assistant Engineer, and Principal Assistant Engineer. Thereafter, he was Assistant Engineer to the Engineer of Construction of the New York, New Haven and Hartford Railroad, on four-track improvements near New York City until 1897. From 1897 until 1906 he was in private practice at Hartford, Conn., engaged in general engineering work.

In 1906, Mr. Vorce entered the employ of Sanderson and Porter, Engineers, and was thereafter actively connected with important railway and hydraulic construction in the New York and San Francisco offices of that firm. Later, he entered the employ of the British Columbia Electric Railway Company as Engineer of Railways, in which position he had charge of all new construction and of the maintenance of all lines, making a notable record in design and in rapid economical execution of track work in paved districts, involving large expenditure.

He left this work to re-enter the employ of Sanderson and Porter, and was associated continuously with the work of the New York office from 1914 until his death, which occurred at Roosevelt Hospital, in New York City, on February 4th, 1918, after an operation from the effects of which he failed to rally.

All who knew Mr. Vorce and his work considered him to be an engineer of exceptional ability and sound judgment. He was a member of the Electric Railway Association and Past-President and member of the Connecticut Society of Civil Engineers.

In 1892, he was married to Miss Virginia Osborn, of New Haven, Conn., who, with a daughter, survives him.

Mr. Vorce was elected a Junior of the American Society of Civil Engineers on April 30th, 1895; an Associate Member on October 7th, 1896; and a Member on May 2d, 1900.

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* Memoir prepared by friends of Mr. Vorce in the office of Sanderson and Porter, Engineers.

AUGUSTINE WASHINGTON WRIGHT, M. Am. Soc. C. E.*

Died February 3d, 1918.

Augustine Washington Wright, the son of John Stephen and Catharine Blackburn (Turner) Wright, was born in Chicago, Ill., on May 29th, 1847, his father having been one of the pioneer settlers of that city.

After his preliminary education at the public schools, Mr. Wright studied mathematics with a private tutor. In April, 1867, he began his engineering work on the Eastern Division of the Union Pacific Railway, and, in 1867 and 1868, was employed in various capacities on the surveys for that road across the plains of Kansas, Nebraska, and Colorado.

During 1869, he was engaged as Division Engineer on the location and construction of the Lexington and St. Louis Railroad, and, in 1870 and a part of 1871, he was connected with the South Branch of the Louisiana and Missouri River Railway in the same capacity.

In the latter part of 1871, Mr. Wright was appointed Assistant Engineer on the Arkansas Central Railway and, in 1872, he served as Chief Engineer of the same road.

In 1873, he returned to Chicago, Ill., as Engineer and Superintendent of the Ransome Stone Works, which position he held until 1875, when he was appointed Chief Engineer of the Federal Creek Valley Railroad. He also served, in 1876, as Chief Engineer of the St. Louis and Toledo Air Line Railroad.

In the latter part of 1877, Mr. Wright became Chief Engineer and General Superintendent of the Havana, Rantoul, and Eastern Railway. He had become interested in steel cable railroads, however, and, in 1878, he resigned this position, to accept that of Chief Engineer and Superintendent of Track and Construction of the North Chicago City Railway, the cable system established in Chicago by the late Charles T. Yerkes.

Mr. Wright remained with the North Chicago City Railway for a number of years. In 1889 and 1890, he built the first cable railroad in Los Angeles, Cal., and, at the same time, he had two cable lines under construction in St. Louis, Mo. He also acted as Consulting Engineer in connection with the construction of first traction railway in New York City. When Mr. Wright retired from active railroad work in 1890, he had become such an authority on traction work that he was called in to advise in a consulting capacity on such construction in all parts of the United States.

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* Memoir prepared by the Secretary from information furnished by Paul Shoup, Esq., and on file at the Headquarters of the Society.

In 1899, Mr. Wright gave up his consulting practice in Chicago, Ill., and settled with his family at Pomona, Cal., where he became a rancher on a large scale. In 1912, however, he sold his property at Pomona and removed to Los Angeles, where, on June 24th, 1913, he was appointed a member of the Board of Public Utilities. On January 4th, 1915, he was re-appointed to succeed himself, and served as a member of the Board until January 1st, 1918, when he resigned on account of ill health. From December 17th, 1913, to January 27th, 1915, he had served as President of the Board.

Mr. Wright was one of the foremost traction men in the United States and an able engineer of wide experience. He died at his home in Los Angeles, Cal., on February 3d, 1918, and is survived by his widow, who was Miss Natalie Jordan, of St. Louis, Mo., to whom he was married on January 1st, 1890, and by two daughters and a son, the latter a student at Stanford University.

Mr. Wright was elected a Member of the American Society of Civil Engineers on May 5th, 1886. He was also a member of the Western Society of Engineers, having served as its President in 1886-87.

EDWARD McKIM HAGAR, Assoc. M. Am. Soc. C. E.*

Died January 18th, 1918.

Edward McKim Hagar was born at Salem, Mass., on June 21st, 1873.

In 1893, at the age of twenty, he was graduated from Massachusetts Institute of Technology, and, a year later, completed a post-graduate course at Cornell University.

Mr. Hagar began his business career with the organization, at Chicago, Ill., of the firm of Edward M. Hagar and Company, a machinery sales concern representing the Mesta Machine Company, the Southwark Foundry and Machine Company, and others.

When the United States Steel Corporation was formed, in 1900, Mr. Hagar was made General Manager of the Cement Department of the Illinois Steel Company, at Chicago. On October 1st, 1906, the Universal Portland Cement Company, a subsidiary of the United States Steel Corporation, was organized, and he was elected its President. During his connection with the cement industry Mr. Hagar served for two years as President of the Association of American Portland Cement Manufacturers, and also organized the Cement Products Exhibition Company which held its first annual industrial exhibition in 1907.

On January 28th, 1915, he resigned the Presidency of the Universal Portland Cement Company to organize a new cement company for the purpose of acquiring and operating a chain of strategically located cement plants across the continent. He is credited with failure to finance this venture, but to the uninitiated the following sidelight is interesting. A preliminary agreement had been reached with certain New York bankers and a plan of financing approved. Mr. Hagar and his attorney were just entering the elevator of the building in which the bankers were located, with the papers drawn up and approved, ready for final signatures, when the announcement of the *Lusitania* sinking was made. The bankers said, "We had better wait until we see what this means."

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* Memoir prepared by E. W. Burbott, Esq.

About this time, Mr. Hagar was called to New York City by another group of financiers and offered the Presidency of The Wright Company, which had just acquired control of the Simplex Automobile Company for the purpose of building the remarkable "Hispano-Suiza" aeronautic motor, now well known at the front abroad. Later, The Wright Company took over the Glenn L. Martin Company of Los Angeles, Cal., aeroplane manufacturers, and the Wright-Martin Aircraft Corporation was organized and Mr. Hagar elected its President on September 8th, 1916. Here his great belief and enthusiasm in the ultimate future of the aircraft industry could not be confined within the limits set by his Board of Directors, and, on February 17th, 1917, he resigned the Presidency of that Corporation.

He next became connected with the American International Corporation, where he organized, and, on September 7th, 1917, was elected President of, the American International Steel Corporation, a subsidiary formed for the purpose of merchandising American steel and steel products abroad. Mr. Hagar retained this position until his death which occurred at his residence, 960 Park Avenue, New York City, on January 18th, 1918, of acute pneumonia, after an illness of only five days.

He was a member of the following societies and clubs: American Society of Mechanical Engineers; American Society for Testing Materials; Western Society of Civil Engineers; American Institute of Mining Engineers; Automobile Club of America; Technology Club of New York; New York Yacht Club; Engineers Club; University Club; The Recess; Duquesne Club of Pittsburgh; Chicago Club; and the Phi Kappa Psi Fraternity.

Mr. Hagar was elected an Associate Member of the American Society of Civil Engineers on February 6th, 1901.

LOUIS WACHTEL, Assoc. M. Am. Soc. C. E.*

Died October 10th, 1917.

Louis Wachtel was born in Gloversville, N. Y., on December 9th, 1885. He spent his boyhood in Gloversville and received his early education in the public schools of that place. After graduating from the High School in 1903, he entered Union College to prepare for his future profession as a Civil Engineer. While there he was a member of the Delta Phi Fraternity.

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* Memoir prepared by J. H. Sturdevant, Assoc. M. Am. Soc. C. E.

After leaving college in 1906, Mr. Wachtel entered the employ of the New York State Highway Department as a Chainman. By his capabilities and industry, he steadily advanced through the various civil service grades until he had reached the rank of Assistant Engineer, when he was compelled to give up active work on account of ill health.

Mr. Wachtel was extremely well liked by all his associates, and it was with great sorrow that his many friends learned of his death on October 10th, 1917, at Welles, N. Y., where he had spent the last few years of his life. By his work and conduct, which were always beyond criticism, he gave promise of going far in his profession.

He was married in 1913, to Miss Pauline L. Cohn, of Saratoga Springs, N. Y., who survives him.

Mr. Wachtel was elected a Junior of the American Society of Civil Engineers on March 2d, 1909, and an Associate Member on September 2d, 1914.

ROGER TAPPAN, Jun. Am. Soc. C. E.*

DIED DECEMBER 6TH, 1916.

Roger Tappan, the son of the Rev. Daniel Dana Tappan and Abigail (Marsh) Tappan, was born in Marshfield, Mass., on November 27th, 1848.

After his graduation from the Massachusetts Institute of Technology, Mr. Tappan was employed as an Assistant Engineer on the northern extension of the old Eastern Railroad. He was afterward engaged as an Assistant on the Engineering Staff of the Fitchburg Railroad during the construction of the Hoosac Tunnel, and had charge of railroad surveys in the Adirondack Mountains, as well as in several of the Western States. His last engineering work was as Engineer in charge of the survey for the North Conway and Mt. Kearsage Railroad, a proposed line up Mt. Kearsage, in New Hampshire, which was never constructed.

As a young man, Mr. Tappan had taught drawing in the public schools of Salem and Haverhill, Mass., and about 1890, he gave up engineering work to devote his time to painting in water colors and oils. He studied art in Boston, New York City, and Paris, and spent much of the latter part of his life abroad.

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* Memoir prepared by the Secretary from information on file at the Headquarters of the Society.

He died on December 6th, 1916, at Natick, Mass., and was buried at Topsfield, Mass. He is survived by his second wife, who was Miss Anna Moberg, of Sjundea, Finland, his first wife, Miss Elizabeth Carleton, of Haverhill, Mass., having died in 1890.

Mr. Tappan was elected a Junior of the American Society of Civil Engineers on December 3d, 1884.

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